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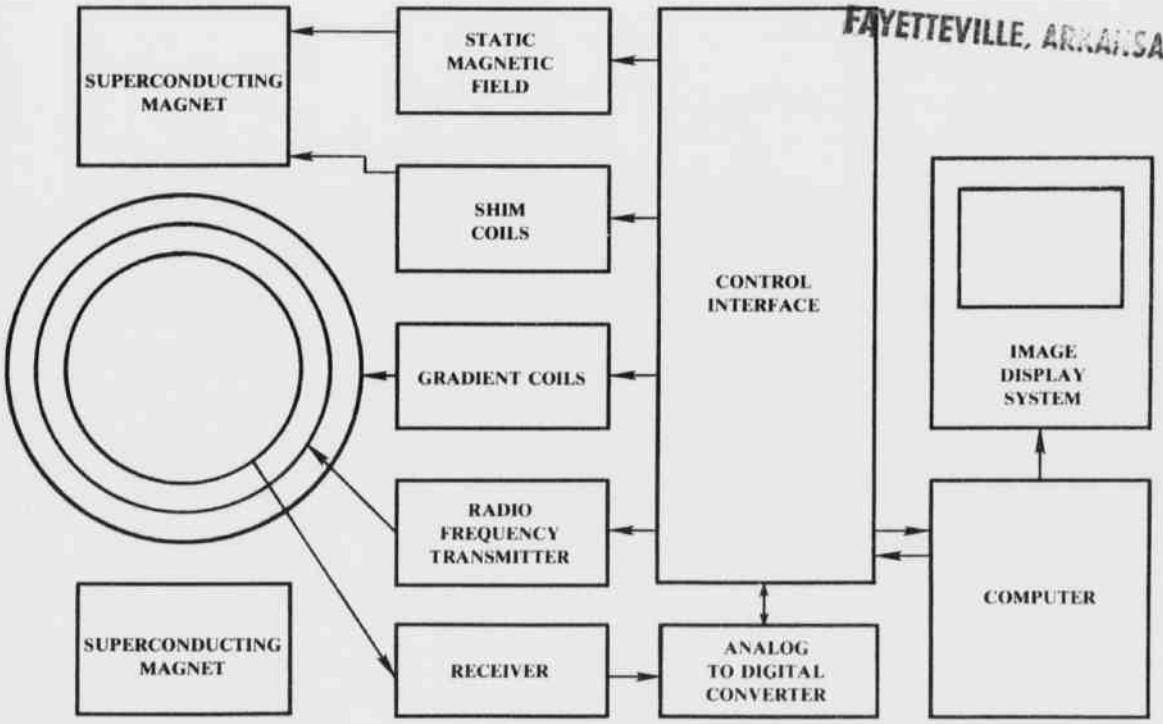

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Flora Haas, 1934
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L. B. Ham, 1936
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M. J. McHenry, 1938
T. L. Smith, 1939
P. G. Horton, 1940
I. A. Willis, 1941-42
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Jeff Banks, 1945
H. L. Winburn, 1946-47
E. A. Provine, 1948
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John R. Totter, 1950
R. H. Austin, 1951
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Edward Dale, 1975
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Joe Nix, 1978
P. Max Johnston, 1979
E. Leon Richards, 1980
Henry W. Robison, 1981
John K. Beadles, 1982
Robbin C. Anderson, 1983
Paul Sarrah, 1984
William L. Evans, 1985
Gary Heidt, 1986
Edmond Bacon, 1987
Gary Tucker, 1988)
David Chittenden, 1989
Richard K. Spears, Jr. 1990

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EDITORIAL STAFF

COVER: Schematic of a typical Magnetic Imaging Spectrometer. Rao P. Gullapalli, Teresa Evans, and Roger Hawk.

ARKANSAS ACADEMY OF SCIENCE

April 6-7, 1990
74th Annual Meeting

ARKANSAS STATE UNIVERSITY

CORRECTION

The program as printed in Volume 43 was in error as to the location of the seventy-third annual meeting.

The correct location of the seventy-third annual meeting was:

THE UNIVERSITY OF ARKANSAS FOR MEDICAL SCIENCES

LITTLE ROCK, ARKANSAS

PROCEEDINGS
ARKANSAS ACADEMY OF SCIENCE

Volume XXXXIV **1990**

Secretary's Report

MINUTES OF THE SEVENTY-THIRD ANNUAL MEETING - APRIL 1990

FIRST BUSINESS MEETING

President Spears called the meeting to order at 1245.

1. Spears called Dave Chittenden to offer welcome to Arkansas State University. Chittenden also introduced the scheduled dinner speaker, Dr. Bassam Shakhashiri. Chittenden also extended offers of assistance from the various department offices located in the building.

2. Spears called Historian, Henry Robison, to give a history of Academy of meetings on the ASU campus. The Academy met here in 1952, 1967, 1973, 1980 and 1990.

3. Spears called on the Secretary (Rickett) who presented the minutes from the 1989 Annual Meeting and asked for corrections or additions. Motion (Rickett, 2nd Rapp): To approve and accept the minutes as distributed contingent on receipt of corrections or additions. Secretary also called for corrections for his membership records. Secretary also asked any motions to be submitted in writing.

4. Spears called on the Treasurer (Wiley) who presented the financial report with some explanation. The current financial status of the Academy is judged best ever. Wiley asked authors to pay page charges as soon as possible. Discussion arose re: page charges not collected. Wiley explained the mechanism is to refuse any further manuscripts from authors who have not paid past page charges. Spears appointed an Audit Committee of Art Johnson, Tom Foti and Bill Bowen.

ARKANSAS ACADEMY OF SCIENCE

ANNUAL FINANCIAL STATEMENT

(20 MARCH 1989 TO 20 MARCH 1990)

Balance Approved by Audit on 8 April 1989		$9980.48
Total Income (Page 2)	15,821.86	
Total Expenses (Page 3)	- 8,939.03	
Balance for the Year	6,882.83	6882.83
TOTAL FUNDS AS OF 20 MARCH 1990		$16,863.31

DISTRIBUTION OF ACCOUNTS

Interest Bearing Checking Account (Union Bank and Trust Co., Monticello, AR)	1033.07
Certificates of Deposit	
Dwight Moore Endowment (Heritage Federal Savings and Loan - Monticello - No. 504891 - 7.75% Interest)	1463.90
Life Membership Endowment (Heritage Federal Savings and Loan - Monticello - No. 504883.1 - 7.75% Interest)	7594.90
AAS Endowment (Heritage Federal Savings and Loan - Monticello - No. 507557 - 7.75% Interest)	6771.44
TOTAL	$16,863.31

Respectfully Submitted,

R. Wiley

Robert W. Wiley, AAS Treasurer

Annual Meeting: 6-7 April 1990
Arkansas State University, Jonesboro, AR

Page 2. Financial Statement, Arkansas Academy of Science, 20 March 1990

INCOME: 20 March 1989 to 20 March 1990

1.	INDIVIDUAL MEMBERSHIPS		
	a. Regular (167)	2505.00	
	b. Sustaining (20)	440.00	
	c. Sponsoring (3)	90.00	
	d. Life (17)	1800.00	
	e. Associate (6)	30.00	
	Total	4865.00	4865.00
2.	INSTITUTIONAL MEMBERSHIPS (17)		1700.00
3.	PROCEEDINGS, LIBRARY SUBSCRIPTIONS		681.00
4.	PROCEEDINGS, MISC. SALES (UAF)		3558.94
5.	PROCEEDINGS, PAGE CHARGES		3447.50
6.	ANNUAL MEETING: UNIVERSITY OF ARKANSAS FOR MEDICAL SCIENCES, 7-8 APRIL 1989		772.15
7.	INTEREST		
	a. Interest Bearing Checking Account	101.99	
	b. Dwight Moore Endowment	95.84	
	c. Life Membership Endowment	303.92	
	d. AAS Endowment	190.52	
	Total	692.27	692.27
8.	ENDOWMENT DONATIONS		
	a. Dwight Moore Endowment	50.00	
	b. AAS Endowment - Unrestricted	55.00	
		105.00	105.00
	TOTAL INCOME		$15,821.86

Page 3. Financial Statement, Arkansas Academy of Science, 20 March 1990

EXPENSES: 20 March 1989 to 20 March 1990

1.	AWARDS		
	a. Bryant Turbeville (#536)	25.00	
	b. D. K. Cartwright (#539)	25.00	
	c. Anders Amelin (#540)	50.00	
	d. John D. Peck, Plaque - Arkansas Science Talent Search (#541)	43.58	
	e. Arkansas Junior Academy of Science (#537)	250.00	
	f. Arkansas Science Fair Association (#536)	200.00	
	Total	593.58	593.58
2.	PROCEEDINGS		
	a. Phillips Litho (Vol. 42) (#533)	7210.15	
	b. Robin Matthews, Editorial Consultant Vol. 42 (#531)	500.00	
	Total	7710.15	7710.15
3.	OFFICE EXPENSES		
	a. Secretary's Office		
	Walt Godwin (#543,#544)	190.98	
	John Rickett (#545)	125.00	
	b. Treasurer's Office		
	Dimcount Office Products (#542)	6.89	
	Total	322.87	322.87
4.	ANNUAL MEETING EXPENCES (UAMS)		
	a. The Shirt Shop (Plaque) (#532)	39.22	
	b. David Chittenden (Plaques) (#523)	86.38	
		125.60	125.60
5.	NEWSLETTER		
	a. Dean's Office - ATU (#534)	88.63	
	b. Agri. Exp. Station (#547)	38.24	
	c. UAM Act. No 11-5-11023 (#550)	30.16	
		157.03	157.03
6.	DUES - National Association of Academies of Science (#548)		29.80
	TOTAL EXPENSES		$8939.03

5. Speairs asked the Secretary to report on the membership. The Academy probably has as many members as ever, but several are in arrears.

6. Speairs called on the *Proceedings* Editor (Barton) who reported that the current issue of the *Proceedings* is finished and available at the registration desk. Barton also asked authors to submit manuscripts intended for publication at this meeting. Motion (Barton, 2nd Beadles): That the Academy appropriate $500 for editorial assistance in the preparation of Volume 44 (1990) of the *Proceedings*.

7. Speairs called on the Newsletter Editor (Kluender) who reported on a successful year. Motion (Kluender, 2nd Robison): That the Academy appropriate $250 to cover the cost of the 1990-91 Newsletter. Kluender asked for clarity and promptness of information for the Newsletter.

8. Speairs called on the Director of Arkansas Science Fairs (Rapp) who reported that 800-1000 students participated. Rapp commended the regional directors. Motion (Rapp, 2nd Anderson): That the Academy appropriate $200 to support the activities of the Arkansas Science Fairs in 1990-91.

9. Speairs called for a report from the Arkansas (Westinghouse) Science Talent Search. Mike Rapp (for John Peck, in absentia) reported the winner was Michael L. Harrison of Batesville, AR with the paper, "My Formula Governing Higher Sums." His sponsor was Mr. Paul Reynolds of Batesville Senior High School. Motion (Rapp, 2nd Robison): That the Academy appropriate $100 to support the Arkansas Science Talent Search in 1990-91. Speairs also announced the Junior Science & Humanities Symposium was successful.

10. Mike Rapp (for Paul Krause, in absentia) submitted a Motion (2nd Robison): That the Academy appropriate $250 to support the Junior Academy of Science in 1990-91.

11. Speairs asked for the report from the Nominating Committee. Mike Rapp (for Don Culwell, Joe Guenter and Neal Buffaloe) submitted Alex Nisbet's nomination for Vice President (2nd Barton). Floor opened: Rapp nominated Mark Draganjac, and Betty Speairs nominated Art Johnson. Beadles moved the nominations cease. Passed.

Floor opened for nominations to the office of Historian. Speairs nominated Henry Robison. No other nominations were received.

12. Speairs announced there was no report from the Biota Committee, but next year additional lists will be available.

13. Speairs called on Robbin Anderson who reported on the Science Education Committee. Anderson explained the restructuring of the committee and announced an open meeting to draw up plans for future activities.

14. Speairs appointed a Resolutions Committee of Gary Heidt, Dan England and John Pauley.

15. Speairs announced the presence (at this evening's dinner) of Dr. David Luck, Chairman of the Board of Higher Education. He should be available for questions.

16. Speairs announced that no invitation has been received for the 1992 meeting. Maybe one will come forth for the second business meeting.

17. Speairs asked the section chairmen to stay on time.

18. Speairs announced the social hour from 5-6 pm at the Ramada Inn.

President Speairs adjourned the meeting at 1320.

SECOND BUSINESS MEETING

President Speairs called the meeting to order at 1202 pm.

1. Speairs called for the approval of the minutes of the business meetings of the 1989 Annual Meeting of the Academy. Passed as presented.

2. Speairs called on the Aduit Committee for a report. Art Johnson submitted a statement that the Audit Committee had examined the Treasurer's records and found them to be in order, having been kept with prudence. Motion (Johnson, 2nd Robison): That the Academy accept the Audit Committee's report. Passed.

Speairs then called for approval of the Treasurer's report. Passed without amendment.

3. Speairs called the Secretary to restate the motions made at the first business meeting for appropriations.

Motion (Barton, 2nd Beadles): $500 for editorial assistance
Motion (Kluender, 2nd Robison): $250 for the Newsletter
Motion (Rapp, 2nd Anderson): $200 for the Science Fairs
Motion (Rapp, 2nd Robison): $100 for the Science Talent Search
Motion (Rapp, 2nd Robison): $250 for the Junior Academy of Science

Secretary's Report

All motions passed with one vote without discussion.

4. Speairs asked Chittenden to report on the paper judging and announce the winners. Teresa Hines (UALR) won the life sciences award, A. Alzaam (UALR-GIT) won the physical sciences award, and M.D. Fletcher (ASU) won the graduate student award.

5. Speairs conducted the election of new officers. Robison was elected by acclamation to a new (5-year) term of Historian. Written ballots elected Art Johnson as Vice President.

6. Speairs called for the report from the Resolutions Committee, which was read by the Secretary:

Be it resolved that:

The members of the Arkansas Academy of Science express their sincere appreciation to the faculty, staff and students of Arkansas State University for hosting our 1990 meeting in their beautiful new facilities. The membership takes this opportunity to especially thank Dr. Larry Boucher, the Local Chairman and his local arrangements committee for the many hours they have worked on behalf of the membership to make this meeting such a success. The membership would like to draw attention to the meeting program in order to identify and thank the section chairpersons and individual presenters for an outstanding job.

Thanks are also extended to Richard K. Speairs, president; Robert L. Watson, president-elect; David Chittenden, immediate past president; the remaining officers and other members of the Executive Committee and other committees to the Academy whose cooperative efforts were so apparent during the meeting.

Finally we thank Dr. Bassam Shakhashiri for his enlightening address and the Reng Center for providing an excellent dinner.

— Gary Heidt, John Pauley, Dan England

Motion (Harp, 2nd Godwin): That the report of the Resolutions Committee be approved. Passed.

7. Speairs called for old business. None was forthcoming.

8. Speairs called for new business.

   a. H. Robison announced the 1991 meeting will be the 75th Anniversary meeting for the Academy, and he is planning a historical display. He requested pictures of past officers and Academy events for this display.

   b. Speairs expressed appreciation for faculty and student support of the Academy meetings.

9. Speairs passed the gavel to Robert Watson thus installing him as the new President, and Watson presented Speairs an appreciation plaque.

10. Watson's inaugural remarks:

   a. Let's use the 75th Anniversary meeting as an opportunity for reflection on past accomplishments and future encouragement.

   b. Let's get more involved in the Academy — bring students, build alliances with public schools and reclaim old friends in academia.

   c. Pledged service and asked for help and input.

11. Watson requested that as many copies of the *Proceedings* as possible be picked up and delivered to those not present.

12. Kluender asked about an invitation for the 1992 meeting; none has been received. Watson requested people give it serious thought and notify the Executive Committee.

13. Watson expressed thanks to Larry Boucher and the local arrangements committee for their efforts and bid him godspeed as he leaves Arkansas for a new position.

President Watson adjourned the meeting at 1224 pm.

REGULAR MEMBERS 1990

Roger Abernathy	Arkansas State University
Stephen R. Addison	University of Central Arkansas
Syed M. Aijaz	University of Arkansas at Pine Bluff
Bob Allen	Arkansas Tech University
Robert T. Allen	University of Arkansas
Silke Hufnagel Allen	Hendrix College
Cynthia Annett	Univ. of Ark./Fayetteville
John T. Annulis	University of Arkansas at Monticello
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Kenneth M. Ball	Southern Arkansas University
Gwen Barber	University of Central Arkansas
Sara Mills Barnett	Texas Education Agency & UT-Austin
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Vernon Bates	(Botanical Consultant)
John Kenneth Beadles	Arkansas State University
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Arkansas Academy of Science

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Benjamin T. Duhart	University of Arkansas at Pine Bluff
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William C. Guest	University of Arkansas
Jim Guilden	University of Arkansas at Monticello
Rao P. Gullapalli	Universiyt of Arkansas at Little Rock - GIT
Paul Gwinup	Arkansas State University
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Dean Hirschi	University of Central Arkansas
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Duane Jackson	Univ. of Arkansas at Little Rock
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Michael L. Johnson	Nettleton High School
Suzanne M. Jones	Arkansas State University
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Norman Lavers	Arkansas State University
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Burla J. Sims	University of Arkansas at Little Rock
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Kimberly G. Smith	University of Arkansas
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Secretary's Report

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Marcus L. Steele	Henderson State University
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PROGRAM
Arkansas Academy of Science

Seventy-fourth Annual Meeting

6-7 April 1990

ARKANSAS STATE UNIVERSITY

Jonesboro, Arkansas

Meeting concurrently with sessions of

The Collegiate Academy of Science

Friday, 6 April 1990

Paper Sessions

Aquatics/Invertebrates/Lower Vertebrates
Botany
Engineering A
Engineering B
Symposium: Chemistry in the 90's
Hospitality Hour
  Sponsored by University of
  Arkansas for Medical Sciences
Buffet Dinner
Speaker:
  Dr. Bassam Shakhashiri
  National Science Foundation

Saturday, 7 April 1990

Paper Sessions

Biomedical/Microbiology
Geology/Mathematics/Science Education
Chemistry
Higher Vertebrates
Physics

Sigma Xi Breakfast

The traditional Sigma Xi Breakfast will be held at the Ramada Inn on April 7, 1990, beginning at 7:00 a.m.

Acknowledgments

Appreciation is extended to the following exhibitors:

Advanced Scientific, Inc.
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SECTION PROGRAMS

[*Undergraduate Student Competition **Graduate Student Competition]

Friday, April 6, 1990
Afternoon Session

AQUATICS/INVERTEBRATES/LOWER VERTEBRATES
Chairperson: Dr. Henry W. Robison, Southern Arkansas University

THE AQUATIC MACROINVERTEBRATES OF THE ST. FRANCIS SUNKEN LANDS.
B.G. Cochran and G.L. Harp, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

SOME BIOLOGICAL ASPECTS OF *Hydroporus ouachitus* MATTA AND WOLFE (COLEOPTERA: DYTISCIDAE).
George L. Harp, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

BIODIVERSITY OF TRICHOPTERA IN THE OZARK AND OUACHITA MOUNTAINS: A PREVIEW OF THINGS TO COME.
Stephen R. Moulton and Kenneth W. Stewart, Department of Biological Sciences, University of North Texas, Denton, TX 76203, and Henry W. Robison, Southern Arkansas University, Magnolia, AR 71753.

REPRODUCTIVE PHENOPHASES AND CLUTCH CHARACTERISTICS OF SELECTED ARKANSAS AMPHIBIANS.
Stanley E. Trauth, Department of Biological Sciences, Arkansas State University, State University, AR 72467; Brian P. Butterfield, Department of Zoology and Wildlife Sciences, Auburn University, Auburn University, AL 36849; Walter E. Meshaka, Archbold Biological Station, P.O. Box 2057, Lake Placid, FL 33852; David A. Saugey, U.S. Forest Service, P.O. Box 255, Mt. Ida, AR 71957; and Robert L. Cox, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

INTERSECTION OF CHIRONOMIDAE (DIPTERA) AND MERMITHIDAE (NEMATODA) FAMILIES AT FOUR GLACIAL LAKES IN CLEARWATER COUNTY, MINNESOTA.
Clarence E. McMahon, Hendrix College, Conway, AR 72032.

TRANSOVARIAN TRANSMISSION OF *Pleistophora ovariae* IN THE GOLDEN SHINER *(Notemigonus crysoleucus)*.
Lawrence W. Hinck and Stanley E. Trauth, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

GENERATING COST ESTIMATES FOR BAITFISH PRODUCTION IN ARKANSAS.
Gayle Pounds, Larry Dorman, and Carole Engle, Department of Agriculture, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

BIOLOGY OF THE GRAVEL CHUB *Erimystax x-punctata* (CYPRINIDAE), IN THE OUACHITA RIVER SYSTEM, ARKANSAS.
John L. Harris, Environmental Division, Arkansas Highway and Transportation Department, Little Rock, AR 72203.

ADDITIONAL DISTRIBUTION RECORDS FOR THE OUACHITA MADTOM, *Noturus lachneri* (ICTALURIDAE), FROM THE OUACHITA RIVER SYSTEM.
John L. Harris, Environmental Division, Arkansas Highway and Transportation Department, and Henry W. Robison, Department of Biology, Southern Arkansas University, Magnolia, AR 71753.

A LIGHT TRAP SURVEY OF THE FEMALE ADULT MOSQUITOES OF CRAIGHEAD COUNTY, ARKANSAS, IN 1986 AND 1987.
Richard E. Holman and Larry A. Olson, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

THE STATUS OF *Eurycea tynerensis* IN NORTHERN ARKANSAS.
Alvan A. Karlin, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204, and Paul Polechla, Department of Zoology, University of Arkansas at Fayetteville, Fayetteville, AR 72701.

*MERMITHID NEMATODES: A COMPARISON OF PRESERVATION FOLLOWING CRITICAL POINT DRYING AND HEXAMETHYLDISILIZANE DRYING.
Chris C. Hemann and A. Johnson, Department of Biology, Hendrix College, Conway, AR 72032, and W. Bowen, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

*COMPARISON OF WATER QUALITY IN STREAMS FROM DIFFERENT ECOREGIONS IN INDEPENDENCE COUNTY, ARKANSAS.
E. Winnifred Fraser, Arkansas College, Batesville, AR 72501, and Jennie F. Weston, Box 84, Cave City, AR 72521.

BOTANY
Chairperson: Dr. Robert Wright, University of Central Arkansas

SCREENING RICE (*Oryza sativa* L.) GENOTYPES FOR DROUGHT TOLERANCE UNDER FIELD CONDITION.
Mazo Price, and Md. Jalaluddin, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601, and R.H. Dilday, USDA/ARS, Stuttgart, AR 72160.

SENSITIVE PLANT SPECIES OF THE "WINDING STAIRS" AREA, LITTLE MISSOURI RIVER, OUACHITA NATIONAL FOREST.
Vernon Bates, P.O. Box 1473, Mena, AR 71953.

A NEW COMPOSITAE SPECIES FROM THE OUACHITA MOUNTAINS OF ARKANSAS.
Albert B. Pittman and Vernon Bates, Department of Arkansas Heritage, 225 East Markham, Suite 200, Little Rock, AR 72201, and Robert Kral, Department of Biology, Vanderbilt University, Nashville, TN 37235.

PRAIRIE RESTORATION IN NORTHWEST ARKANSAS.
Edward E. Dale, Jr., Department of Botany and Microbiology, University of Arkansas, Fayetteville, AR 72701.

THE VEGETATION OF SARATOGA LANDING BLACKLAND PRAIRIE.
Thomas L. Foti, Arkansas Natural Heritage Commission, Department of Arkansas Heritage, 225 East Markham Street, Little Rock, AR 72201.

ALLOZYME AND MORPHOMETRIC VARIATION IN *Haplopappus gracilis*.
Kenneth J. Freiley, University of Central Arkansas, Conway, AR 72032.

PHOTOSYNTHETIC COMPETENCE OF AN ENDANGERED SHRUB, *Lindera melissifolia*.
Robert D. Wright, University of Central Arkansas, Conway, AR 72032.

**SEXUAL DIMORPHISM AND INTERSEXUAL DIFFERENCES IN RESOURCE ALLOCATIONS OF A DIOECIOUS SHRUB, *Lindera melissifolia* (WALT.) BLUME.
Dennis J. Richardson, Robert D. Wright, and Shannon Walker, Department of Biology, University of of Central Arkansas, Conway, AR 72032.

*A COMPARISON OF METHODS FOR EXTRACTING DNA FROM RICE.
Theresa L. Hines, Neela R. Patel, Michael L. Sikes, Daoud Abu-Diab, and Alvan A. Karlin, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

**USING NON-NODULATING SOYBEANS TO ESTIMATE BIOLOGICAL NITROGEN FIXATION.
W.F. Johnson, Jr., D.C. Wolf, and T.K. Walker, Department of Agronomy, University of Arkansas, Fayetteville, AR 72701.

**CHARACTERIZATION AND SELECTION OF SOFT WHEAT FOR NITROGEN UTILIZATION.
J.T. Kelley and R. K. Bacon, Department of Agronomy, University of Arkansas, Fayetteville, AR 72701.

REVISING THE TAXONOMY OF THE TWO MOST COMMON MICROSCOPIC SLIME MOLDS.
Frederick W. Spiegel, Department of Botany and Microbiology, University of Arkansas, Fayetteville, AR 72701.

ENGINEERING 1-A
Chairperson: Dr. Robert Engelken, Arkansas State University

**EVALUATION OF WETTING AGENT EFFECTS ON THE BEER COATING OF POLISHED SILICON WAFERS.
Gary Fuller, Kamesh Gadepally, and Roger Hawk, University of Arkansas at Little Rock, ETAS 575, 2801 South University, Little Rock, AR 72204.

**STUDY OF AN ELECTROSTATIC SPRAY DEPOSITION METHOD USING SILICON POWDER.
Kamesh V. Gadepally, Kevins B. Tennal, and Roger M. Hawk, Electronics and Instrumentation Department, University of Arkansas at Little Rock, ETAS 575, 2801 South University Avenue, Little Rock, AR 72204; Al Robles and James A. Gribles, Ameron Powder Coating Co., P.O. Box 9610, Little Rock, AR 72219.

**ELECTROSTATIC CHARGE CHARACTERIZATION OF TONERS IN LASER PRINTING PROCESS.
Chaoping Wu, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, 2801 South University, Little Rock, AR 72204.

**CHARACTERIZATION OF RADIOACTIVITY IN HOT SPRINGS NATIONAL PARK, ARKANSAS.
C.E. Epperson and N.R. Rhodes, University of Arkansas for Medical Sciences, College of Pharmacy, 4301 West Markham, Little Rock, AR 72205.

**PHOTOACOUSTIC DETECTION OF CARBONACEOUS ATMOSPHERIC AEROSOLS.
Duane Jackson, University of Arkansas at Little Rock, Department of Electronics and Instrumentation, 2801 South University, Little Rock, AR 72204.

**AN ON-LINE PROCESS FIBER OPTIC REFRACTOMETER FOR MEASURING EDIBLE OILS.
Charles F. Cole, Jr., University of Arkansas at Little Rock, Department of Electronics and Instrumentation, 2801 South University, Little Rock, AR 72204.

**DETERMINATION OF ALUMINUM BINDING TO ADENINE NUCLEOSIDES.
Susan G. Brown and Roger M. Hawk, University of Arkansas at Little Rock, Department of Electronics and Instrumentation, 2801 South University, Little Rock, AR 72204.

*PREPARATION OF PHOTOCONDUCTIVE METAL SULFIDE FILMS BY COMBINED MINIMAL HAZARD CHEMICAL PRECIPITATION/ION EXCHANGE PROCESSES.
Robert Engelken, Shahzad Ali, Lip Ngin Chang, Charles Brinkley, and Kevin Turner, Arkansas State University, Department of Engineering, P.O. Box 1740, State University, AR 72467.

ENGINEERING 2-A
Chairperson: Dr. Roger Hawk, University of Arkansas-Little Rock

INTERDISCIPLINARY RESEARCH IN MICROELECTRONICS AT UAF BETWEEN CHEMICAL AND ELECTRICAL ENGINEERING.
R.K. Ulrich, Department of Chemical Engineering, University of Arkansas, Fayetteville, AR 72701; W.A. Brown, S.S. Ang, and H.A. Naseem, Department of Electrical Engineering, University of Arkansas, Fayetteville, AR 72701.

ENGINEERING AND SCIENTIFIC RESEARCH AT PREDOMINANTLY UNDERGRADUATE INSTITUTIONS: CHALLENGES, TOOLS, AND OPPORTUNITIES.
Robert Engelken, Department of Engineering, P.O. Box 1740, Arkansas State University, State University, AR 72467.

A MULTI-DISCIPLINARY RESEARCH LABORATORY AT MISSISSIPPI STATE UNIVERSITY — THE DIAGNOSTIC INSTRUMENTATION AND ANALYSIS LABORATORY.
Robert L. Cook, Richard D. Benton, and Robert A. Green, Mississippi State University, Diagnostic Instrumentation and Analysis Laboratory, P.O. Drawer MM, Mississippi State, MS 39762.

A GRADUATE EDUCATION OPPORTUNITY IN OCCUPATIONAL AND ENVIRONMENTAL HEALTH.
Thomas W. Rimmer, University of Arkansas at Little Rock, Department of Electronics and Instrumentation, 2801 South University, Little Rock, AR 72204.

ENGINEERING: ART, SCIENCE, OR TRADE.
Robert A. Green, Mississippi State University, Diagnostic Instrumentation and Analysis Laboratory, P.O. Drawer MM, Mississippi State, MS 39762.

ENGINEERING 1-B
Chairperson: Dr. M.K. Mazumbder, University of Arkansas-Little Rock

A COMPARISON OF PRESSURIZED AND GRAVITY DISTRIBUTION SYSTEMS FOR WASTEWATER TREATMENT.
M.A. Gross, R.T. Muldoon, J.S. Neal, and B. Ederington, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, 2801 South University, Little Rock, AR 72204.

ENGINEERING FIELD THEORY — AN INTERDISCIPLINARY APPROACH.
Leo Setian, Engineering Division, John Brown University, Siloam Springs, AR 72761.

IMAGE ENHANCEMENT OF FADED HISTORIC DOCUMENTS.
Barry G. Wells, Department of History, and Robert M. Crisp, Jr., Department of Engineering, 309 Engineering Building, University of Arkansas, Fayetteville, AR 72701.

DISCUSSION ON THE USE OF g_c IN PHYSICS AND ENGINEERING EDUCATION AND PRACTICE.
Larry Byrd, Department of Engineering, P.O. Box 1740, Arkansas State University, State University, AR 72467.

LABORATORY AUTOMATION USING A MICROPROCESSOR

CONTROLLED SAMPLING OSCILLOSCOPE AND A PERSONAL COMPUTER.
Sanjay K. Mitra, Electronics and Instrumentation Department, University of Arkansas at Little Rock, ETAS-575, 2801 South University Avenue, Little Rock, AR 72204.

IMPLEMENTATION OF A LABORATORY DISTRIBUTED CONTROL SYSTEM.
Claudio A. Hernandez and Robert A. Sims, University of Arkansas at Little Rock, Department of Electronics and Instrumentation, 2801 South University, Little Rock, AR 72204.

THE IMPACT OF MICROPROCESSOR PROTECTED MODE PROGRAMMING ON UNDERGRADUATE EDUCATION IN ENGINEERING TECHNOLOGY.
Robert L. Douglas, Engineering Technology, Memphis, State University, Memphis, TN 38152.

EDUCATIONAL SOFTWARE DEVELOPMENT USING HYPERTEXT AND EXPERT SYSTEM SOFTWARE CONCEPTS.
Siripong Malasri, Knowledge Engineering Center, Christian Brothers College, Memphis, TN 38104-5581.

ENGINEERING 2-B
Chairperson: Dr. Larry Byrd, Arkansas State University

IMPROVEMENT IN ENGINEERING DESIGN RESULTING FROM A UNIFIED THEORY OF SCIENCE.
Joseph M. Brown, Department of Mechanical Engineering, Mississippi State University, Mississippi State, MS 39762.

ENHANCING AN ENGINEERING LEARNING ENVIRONMENT.
Paul Palazolo, School of Engineering, Christian Brothers College, 650 East Parkway South, Memphis, TN 38104-5581.

A GONIOMETER-BASED SYSTEM FOR NEONATAL SCREENING OF CONGENITAL HIP DISEASE.
Gaylen G. Burnside and Paul C. McLeod, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, 2801 South University, Little Rock, AR 72204.

PRINCIPLES AND CLINICAL APPLICATION OF MAGNETIC RESONANCE.
R.P. Gullapalli and R.M. Hawk, Electronics and Instrumentation Department, University of Arkansas at Little Rock, 2801 South University, Little Rock, AR 72204; T. Evans, Chemistry Department, University of Arkansas at Little Rock, 2801 South University, Little Rock, AR 72204; and R.A. Komoroski, Department of Radiology, University of Arkansas for Medical Sciences, Little Rock, AR 72204.

ALKALI METAL NMR IN MEDICINE AND BIOLOGY.
Rao P. Gullapalli and Roger M. Hawk, Electronics and Instrumentation Department, University of Arkansas at Little Rock, Little Rock, AR 72204; and Richard A. Komoroski, Department of Radiology, University of Arkansas for Medical Sciences, Little Rock, AR 72204.

*FLOW PATTERNS AND GAS MIXING IN A SYMMETRICAL LUNG MODEL.
S. Alzaaim, D.L. Wankum, R. Cole, and J. Hammersley, Graduate Institute of Technology, University of Arkansas at Little Rock, ETAS Building, Room 575, 2801 South University, Little Rock, AR 72204.

SYMPOSIUM: CHEMISTRY IN THE 90'S
Sponsored by the Student Affiliates, American Chemical Society, Arkansas State University

INTRODUCTORY REMARKS — Dr. Jack Lay, National Center for Toxicological Research

"COLD FUSION" — Dr. John Hanneken, Department of Physics, Memphis State University.

"ROOM TEMPERATURE SUPERCONDUCTORS?: A PROGRESS REPORT" — Dr. Anny Morrobel-Sosa, Department of Chemistry, University of Alabama.

"HAZARDOUS WASTE DISPOSAL" — Dr. Charles Waggoner, Department of Chemistry, Mississippi State University.

CLOSING REMARKS — Dr. Jack Lay, NCTR

Saturday, April 7, 1990

BIOMEDICAL/MICROBIOLOGY
Chairperson: Dr. Arthur A. Johnson, Hendrix College

Morning Session

TIME COURSE OF PHOTOREACTIVATION OF UV INDUCED DAMAGE IN G1 PHASE *Xenopus* CELLS THAT LEADS TO CHROMOSOME BREAKS OBSERVABLE BY PREMATURE CHROMOSOME CONDENSATION.
Robert Wright, Stephen Ruble, and Gaston Griggs, Biology Department, John Brown University, Siloam Springs, AR 72761.

HEMATOZOA OF CENTRAL ARKANSAS COMMON GRACKLE.
Arthur A. Johnson, Hendrix College, Conway, AR 72032.

ANTIBODY ENHANCEMENT OF CARCINOGEN FLUORESCENCE IN FIBER OPTIC MICROCHEMICAL SENSORS.
A.M. Hoyt, Jr., University of Central Arkansas, Conway, AR 72032, and M.J. Sepaniak, University of Tennessee, Knoxville, TN 37996.

AXONAL GROWTH THROUGH A GLIAL-DEPLETED ENVIRONMENT.
M.A. Pippenger, T.J. Sims, and S.A. Gilmore, Department of Anatomy, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

CHARACTERIZATION OF A 60 KILODALTON RECOMBINANT *Brucella abortus* IMMUNOGENIC PROTEIN.
R.M. Roop II and M.L. Price, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Slot #511, 4301 West Markham Street, Little Rock, AR 72205-7199; S.M. Boyle and G.G. Schurig, Department of Pathobiology, Virginia-Maryland Regional College of Veterinary Medicine, Blacksburg, VA.

CHARACTERIZATION OF THE SIMIAN *Varicella* VIRUS GENOME.
Wayne L. Gray, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Slot #511, 4301 West Markham Street, Little Rock, AR 72205.

**CHARACTERIZATION OF IMMUNOGENIC SIMIAN *Varicella* VIRUS PROTEINS AND GLYCOPROTEINS.
Thomas M. Fletcher III and Wayne L. Gray, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Slot #511, 4301 West Markham Street, Litle Rock, AR 72205.

GEOLOGY/MATHEMATICS/SCIENCE EDUCATION

Chairperson: Dr. Robbin Anderson, University of Arkansas-Fayetteville

**SOIL AND LITHOSTRATIGRAPHY BELOW THE LOVELAND SILT, CROWLEY'S RIDGE, ARKANSAS.
Donna Porter, Geology Department, and Sam Bishop, Geography Department, University of Arkansas, Fayetteville, AR 72701.

EFFICIENCY IN COLLECTING FOSSILS.
Kenneth M. Ball, Department of Biology, and Leo Carson Davis, Department of Physical Sciences, Southern Arkansas University, Magnolia, AR 71753.

A TEST FOR MULTIVARIATE NORMALITY.
Roger Abernathy, Department of Computer Science, Mathematics, and Physics, Arkansas State University, Box 70, State University, AR 72467.

DEALING WITH STUDENTS' PRECONCEPTIONS ABOUT PHYSICS: DOES IT MAKE A DIFFERENCE?
Dean Hirschi, University of Central Arkansas, Physics Department, Lewis Science Center, Room 105, Conway, AR 72032.

PERSISTENCE OF REMEDIAL MATHEMATICS STUDENTS.
Laurence J. Boucher, College of Arts and Sciences, Arkansas State University, P.O. Box 1030, State University, AR 72467.

CHEMISTRY 1

Chairperson: Dr. Bryan Palmer, Henderson State University

*EVALUATION OF EPHEDRINE DERIVATIVES AS POSSIBLE APPETITE SUPPRESSANTS.
M. Mateen Akmal, D. Mark Wood, Mehran Karimi, and Richard B. Walker, Chemistry Department, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

*RELATIONSHIPS BETWEEN MUTAGENICITIES OF NITRATED PHENYLFURANS AND THE PRESENCE AND POSITION OF THE NITRO GROUP.
E. Kim Fifer and Gary Gibson, Department of Biopharmaceutical Sciences, University of Arkansas for Medical Sciences, Little Rock, AR 72205; Ali Shaikh, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204; and Robert H. Heflich, Division of Genetic Toxicology, National Center for Toxicological Research, Jefferson, AR 72079.

*THE POTENTIAL OF SMALL PEPTIDE DERIVATIVES AS BLOOD PRESSURE REGULATING AGENTS.
Cathy Cagle and R.M. McConnell, Chemistry Department, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

*SYNTHESIS OF LEUPEPTIN ANALOGS.
Arnita Jones and Rose M. McConnell, Department of Chemistry, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

*BIOCHEMICAL ASSAY OF LEUPEPTIN ANALOGS.
Amanda Camp and Rose M. McConnell, Department of Chemistry, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

*SYNTHESIS OF PEPSTATIN ANALOGS.
Wanda Jones and Rose M. McConnell, Department of Chemistry, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

THE CHEMISTRY OF ATYPICAL RAINFALLS.
D.M. Chittenden II and W.V. Wyatt, Department of Chemistry, Arkansas State University, State University, AR 72467.

THERMAL DECOMPOSITION STUDIES OF SELECTED TRANSITION METAL POLYSULFIDE COMPLEXES.
Benjamin Rougeau, J.E. Bennett, and M. Draganjac, Department of Chemistry, Arkansas State University, State University, AR 72467.

CHEMISTRY 2

Chairperson: Dr. Arthur Hoyt, Jr., University of Central Arkansas

COMPARISON OF THE MOLECULAR STRUCTURES OF MONOVALENT CATION SALTS OF N,N-DIMETHYLDITHIOCARBAMATE. NOVEL SYNTHESIS AND CRYSTAL STRUCTURE OF $(P\emptyset_4)$ $(S_2CN(CH_3)_2) \cdot 2H_2O$.
M. Draganjac and David Minick, Department of Chemistry, Arkansas State University, State University, AR 72467; and E.M. Holt, Department of Chemistry, Oklahoma State University, Stillwater, OK 74078

*ULTRASOUND IN DECAFFEINATION.
Dominic T.C. Yang and Rommy N. Amadi, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204; and Eric U. Yang, Catholic High School for Boys, Little Rock, AR.

CONFORMATIONAL AND CIRCULAR DICHROISM STUDIES OF N-ACETYL-L-PROLYL-D-ALANYL-METHYLAMIDE.
S. Ramaprasad, Department of Radiology, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

SYNTHESIS OF CHLORINATED POLYCYCLIC AROMATIC HYDROCARBONS: A NEW CLASS OF GENOTOXIC ENVIRONMENTAL CONTAMINANTS.
Dominic T.C. Yang and Fumiko Yamazaki, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

THE EFFECT OF OVERNIGHT FASTING ON GLUTATHIONE CONCENTRATION AND CYTOCHROME P-450 ACTIVITY IN MALE B6C3F1 MICE.
T.A. McRae, D.W. Roberts, and J.A. Hinson, National Center for Toxicological Research, Jefferson, AR 72079; and D. Ferguson, University of Arkansas at Little Rock, Little Rock, AR 72204.

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LIGHTNING: A COMPLEX NATURAL PHENOMENON THAT DEFIES SIMPLE ANALYSIS.
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EFFICIENCY IN COLLECTING FOSSILS

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ABSTRACT

Two hundred seventy-two kilograms of sediments and fossils were collected from 1 meter square plots on lake beach and river gravel bars to compare the efficiency of surface collecting with that of intensive laboratory processing. Collecting fossils by visual inspection of the outcrop required an average of 14 minutes 56 seconds per square meter and resulted in 319 vertebrate and 1320 invertebrate fossils. The ratio of time spent collecting and processing sediments to time spent in surface collecting fossils was 4.66:1. The ratio of invertebrates produced by the intensive laboratory process to invertebrates produced by surface collecting was 4.80:1. Vertebrate fossils produced by the intensive process amounted to only 0.91 of the amount collected on the surface. Surface collecting is, therefore, the more efficient collecting method, particularly for vertebrate fossils.

INTRODUCTION

Many sites along the South Sulphur River of Hunt County, Texas, needed to be sampled to attempt to locate the source of Pleistocene vertebrate remains which make up a minor fraction of a faunal assemblage otherwise dominated by Cretaceous Bivalvia and Chondrichthyes. Different collecting methods involved different costs and produced variable yields. A search of the paleontological literature since 1945 showed that the question of collecting efficiency had been ignored. Most investigators had been willing to invest whatever resources were required in order to collect all a locality had to offer, such as the heavy-liquid flotation treatment of one quarter ton of Cretaceous matrix to produce nine mammal teeth (Lees, Curator 7:300-306, 1964). This unlimited investment approach was deemed too expensive to use in the present study which compared 2 styles of collecting, quantified the results, and proved the superior efficiency of surface collecting over intensive laboratory processing.

METHODS AND MATERIALS

Two sites along the South Sulphur River were studied. The functional unit of this study was 1 meter squares laid out with meter sticks and string on gravel bars. The Neylandville site (Squares 1 through 4) was approximately 7.1 river miles and 6.5 airline miles upstream from the Commerce site which produced Squares 13-1 and 13-3 through 13-8. Three squares from a beach on Millwood Lake, Hempstead County, Arkansas, roughly 120 airlines miles to the east were used to represent a different environment.

The first technique of collection examined in this study required a minimum of processing: visual inspection of the surface for fossils. Time required for surface collecting was measured by electronic stopwatch, as were all time measurements in this study.

The second technique required intensive processing: bulk sampling, sifting, and picking. The top 0.5 inch of sediments in each square was collected by shovel, and the time spent collecting this layer was measured. In the laboratory, the fossils which had been collected on the surface were identified and counted. The fossils were then restored to the surface sediments before further processing. With screens made of hardware cloth with 0.5, 0.25, and 0.125 inch openings, the sediments were separated into 4 fractions: greater than 0.5 inch (coarse), 0.5 inch to 0.25 inch (medium), 0.25 inch to 0.125 inch (fine), and less than 0.125 inch (micro) sizes. The stages of the sifting process were timed.

The coarse (greater than 0.5 inch) and the medium (0.5 inch to 0.25 inch) sediments were then picked visually for fossils. This process was timed. The fossils recovered were then identified and counted. Pebbles, representing errors in picking, were also counted.

RESULTS

Two hundred seventy-two kilograms of sediments from the 14 squares were taken to the laboratory for processing. The collecting times, processing times, and specimens collected are presented in Tables 1-4. In computing processing times for the various sediment sizes, one quarter of the time spent collecting the surface layers and sifting the sediments into size fractions was assigned to each of the 4 fractions. None of the less than 0.125 inch size sediments were examined, and of the fine fraction (0.25 inch to 0.125 inch size), only the sediments from 3 squares

Table 1. Processing Times (in seconds) For Gravel Bar Squares

	1	2	3	4	5	6
Millwood Sq.-1	900	279	781	943	2102	4105
Millwood Sq.-2	901	190	398	940	2637	4165
Millwood Sq.-3	753	276	543	568	3255	4642
Neylandville 1	691	154	650	190	284	3843
Neylandville 2	720	121	1074	226	2486	3907
Neylandville 3	381	161	620	522	1838	3141
Neylandville 4	388	115	655	731	2178	3679
Commerce 13-1	856	211	834	282	2086	3415
Commerce 13-2	1082	183				
Commerce 13-3	1029	186	475	205	2008	2874
Commerce 13-4	821	160	558	552	3704	4974
Commerce 13-5	1334	152	446	284	5253	6135
Commerce 13-6	1448	226	591	347	3752	4916
Commerce 13-7	1207	207	658	245	3288	4398
Commerce 13-8	922	197	430	229	2468	3324

1 Time to surface collect.

2 Time to shovel surface.

3 Total sifting time.

4 Time spent picking sediments larger than 0.5 inch.

5 Time spent picking sediments between 0.5 and 0.25 inch.

6 Total processing time.

Table 2. Numbers of Fossils Found in Surface Collecting (M = Millwood Lake Site, N = Neylandville Site, C = Commerce Site)

	M-1	M-2	M-3	N-1	N-2	N-3	N-4	C-1	C-3	C-4	C-5	C-6	C-7	C-8
Bone	1		5					8	7	8	5	17	11	21
Shark Teeth				4	3	1		10	27	4	22	30	19	12
Barracuda Teeth							1	5	12	2	12	11	4	4
Ray Teeth		1						1	4		1	4	1	
Fish Bones	1	2						2				4		2
Tooth Enamel						1	1	1	3			3	3	4
Sawfish Rostrals						1						1	1	1
Shark Denticles												1		
Crushing Plates												1		
Reptile Teeth									2				2	1
Rodent Teeth											2		1	
Vert. Sum	2	3	5	4	3	3	2	27	55	14	42	72	42	45
Pelecyp. Molds	5		7				7	1	8	1	2	4		3
Pelecypod Shells	19	60	54	225	51	52	131	25	50	45	73	87	74	66
Gastropod Int. Molds		2	1				1	15	27	9	23	29	19	20
Gastropod Ext. Molds						1	1							
Belemnites		1												
Coiled Ammon.		1								1			1	
Straight Ammonites	1						1	3	4			4		
Echinoid Plates		1						1				1		2
Echinoid Spines	2	4	32											
Crinoids		5	9											
Worm Tubes	1	13	4	2				4	3	1	1	1		
Corals								1				1	2	
Crab Claws			1					1				2	1	1
Brachiopod?												2		
Unidentified	2										1			
Petrified Wood				2		1	1	2	1			2		2
Invertebrate Sum	22	93	102	229	51	54	142	53	93	57	100	133	97	94
Total Fossil Sum	24	96	107	233	54	57	144	80	148	71	142	205	139	139
Pebbles	6	8	15	17	1	4		24	14			22		11

Table 3. Numbers of Fossils with Diameter Greater Than ½ Inch (M = Millwood Lake Site, N = Neylandville Site, C = Commerce Site)

	M-1	M-2	M-3	N-1	N-2	N-3	N-4	C-1	C-3	C-4	C-5	C-6	C-7	C-8
Bone				1	5	1	1	1	5	5	2	7	5	6
Shark Teeth												1		
Ray Teeth		1												
Fish Bone		5	1							1				
Tooth Enamel									1				1	
Vert. Sum	0	6	1	1	5	1	1	1	6	6	2	8	6	6
Pelecypod Molds	1		2			6	8				2			
Pelecypod Shells	34	32	41	31	36	74	56	9	18	27	14	24	14	22
Gastropod Internal Molds							3		1		1			2
Coiled Ammonites						4	1							
Straight Ammonites		2				2	1		1	2				
Echinoid Plates		1	1											
Echinoid Spines	2	1	3											
Worm Tubes	1	2	4											
Corals	2													
Unident.	1													
Petrified Wood						2	2	2				2		
Invertebrate Sum	41	38	51	31	36	88	72	11	20	29	17	26	14	24
Total Fossil Sum	41	44	52	32	41	89	73	12	26	35	19	34	20	30
Pebbles	1	4	4	1	2	3		4	3			2		3

Table 4. Numbers of Fossils with Diameters From ½" to ¼" (M = Millwood Site, N = Neylandville Site, C = Commerce Site)

	M-1	M-2	M-3	N-1	N-2	N-3	N-4	C-1	C-3	C-4	C-5	C-6	C-7	C-8
Bone				8	7		2	17	16	10	11	16	7	11
Shark Teeth	2	4		2	2	1	3	11	9	1	11	11	4	7
Barracuda Teeth				1		4	1				4			
Ray Teeth	1	2						2	2	2	2	3		1
Fish Bone	5	3						2		1	2		1	1
Tooth Enamel				1		1	1	4	2		2	2	3	3
Sawfish Rostrals						1							1	1
Reptile Teeth							1		1				1	1
Rodent Teeth												1		
Armadillo Scute											1			
Vertebrate Sum	0	8	9	12	9	7	8	36	30	14	33	33	17	25
Pelecypod Molds	8	8	4	1		1	7	5	3	8	8	8	10	3
Pelecypod Shells	180	370	873	567	569	258	135	293	326	254	195	500	250	496
Gastropod Internal Molds	3	4	4	2	1	1	2	42	30	40	52	52	38	32
Belemnites	1	1												
Coiled Ammonites	1	1					2			4	6		9	
Straight Ammonites	1							4	3			13		3
Echinoid Plates		5	17											
Echinoid Spines	1	4	9											
Crinoids		1	2					1						
Worm Tubes	1	20	20	1				3	1		2	1		
Corals									1	1			1	
Crab Claws				1										
Brachiopod?						1						1		
Unidentified	3						2	2	2					
Petrified Wood	1				2	5	4	3		4	3	6	3	5
Invertebrate Sum	196	417	930	572	572	266	152	353	366	311	266	581	311	539
Total Fossil Sum	196	425	939	584	581	273	160	389	396	325	299	614	328	564
Pebbles	7	14	16	27	5	18	14	24	19	63		38	51	27

were examined. Although 2341 specimens were recovered with an efficiency of 21.1 seconds per fossil, the average time to pick the non-pelecypod fossils from each square was 4.58 hours. Therefore, complete processing of the fine and micro fractions was judged to be too time-consuming for the present study.

DISCUSSION

Overall, surface collecting of vertebrates is more efficient, as measured by number of seconds per fossil collected. Table 5 indicates it requires fewer seconds to collect each specimen of vertebrate fossil by visual inspection of the surface of a gravel bar (38.7 seconds per fossil) than by collecting, sieving, and picking sediments (178.2 seconds per fossil). Therefore, the rate of return from surface collecting averages 4.6 times the rate for fossils in laboratory processing.

Surface collecting of larger invertebrates is also more efficient than intensive processing. Surface collecting has a yield rate of 9.4 seconds per fossil as compared to 18.3 seconds per fossil in intensive processing of coarse sediments, those greater than 0.5 inch. Laboratory processing of medium sediments, on the other hand, had an efficiency of 7.5 seconds per fossil.

If the pelecypod shells are ignored in the samples, surface collecting becomes even more attractive. Many of the pelecypod shell fossils are fragmented and of little paleontological value although they remain identifiable. When they are removed from the total fossil counts, the surface collecting technique has a yield rate of 19.7 seconds per fossil, and the medium sediments produce at a rate of 53.0 seconds per fossil, only 37% the rate of surface collecting. Leaving out the pelecypod fossils drops the rate of return from the coarse sediment fraction to 78.5 seconds per fossil, the lowest return of all.

The number of non-fossiliferous pebbles that are mistakenly picked

Table 5. Collecting Efficiency Ratios (seconds per fossil recovered).

	0.25"-0.5" (a)	> 0.5" (a)	Totals (b)	From Surface (c)
Vertebrates	177.4	182.0	178.2	38.7
All Invertebrates	7.3	18.3	8.2	9.4
Invertebrates Other Than Pelecypod Shells	75.5	137.9	82.0	40.1
Total Fossils	7.0	16.6	7.8	7.5
Total Fossils Other Than Pelecypod Shells	53.0	78.5	56.2	19.7

(a) computed by dividing the number of fossils into 0.25 of the surface shoveling time plus 0.25 of the sifting time plus the picking time for that particular fraction.

(b) computed by dividing the total number of fossils into 0.5 of the surface shoveling time plus 0.5 of the sifting time plus the total picking time for the greater than 0.5 inch and the 0.5 inch to 0.25 inch fractions.

(c) computed by dividing the total number of fossils recovered from the surface by the time spent surface collecting.

out would be an index of inefficiency. From among the surface collected sediments, 122 pebbles were retained. In the coarse sediments 0.29 pebbles per kilogram were retained in laboratory processing, and this index rose to 5.10 errors per kilogram of medium sediments, indicating this fraction presents problems when it is picked without some sort of magnification aid. For the 12,351 seconds of surface collecting, 122 pebbles were collected. This number indicates a span of 101 seconds between "errors," which could be caused by factors hard to control in the field such as poor illumination and a heterogeneous surface. For the 51,844 seconds of processing coarse and medium fractions in the laboratory, the 345 pebbles mistakenly collected indicate a span of 150 seconds between "errors," which is a 49% improvement in performance.

In terms of absolute numbers rather than rates of return, surface collecting produced only 25% (1639) as many total fossils (6621) as laboratory processing (Table 6). If the pelecypod shells are excluded,

Table 6. Numbers of Fossils Recovered.

	0.25"-0.5"	> 0.5"	Totals	From Surface
Vertebrates	241	50	291	319
All Invertebrates	5832	498	6330	1320
Invertebrates Other Than Pelecypod Shells	566	66	632	308
Total Fossils	6073	548	6621	1639
Total Fossils Other Than Pelecypod Shells	807	116	923	627

the surface collecting produced 68% as many fossils as laboratory processing. Of invertebrates, surface collecting produced 21% of the number that was recovered in laboratory processing or 49% of the laboratory-produced invertebrates if pelecypod shells are excluded. Of vertebrates, the 319 fossils recovered by surface collecting were 110% of the 291 found during laboratory processing. Therefore, it is among the vertebrate fossils that surface collecting is particularly effective, probably due in large part to the color contrast these phosphatic fossils make with their matrix. Only one taxon, Pleistocene armadillo scute, was not recovered during surface collecting, but just 1 specimen was recovered during intensive laboratory processing.

As might be expected, the correlation of collecting efficiency between the two Sulphur River localities is high in several respects. The average efficiencies for invertebrate, vertebrate, and total fossils taken in surface collecting, processed coarse sediments, processed medium sediments, and totals of all collections correlated at a level of 0.94. When the average collecting efficiencies for just the vertebrate and invertebrate categories are correlated, a value of 0.92 is obtained, and the correlation for invertebrate categories is at 0.87. Correlation for vertebrates falls to 0.79 since the Neylandville site produced an average of 3.0 vertebrates per surface-collected square meter (Observed Range 2 to 4) and the Commerce site produced an average of 42.4 vertebrates per surface-collected square meter (O. R. 14 to 72). Some of the correlations of collecting efficiencies between Millwood Lake and the Sulphur River localities were high. In the average efficiency for invertebrate, vertebrate, and total fossils taken in surface collecting, processed coarse sediments, processed medium sediments, and totals of all collections, the correlation of Millwood Lake with the Neylandville squares was 0.91, and the correlation of Millwood Lake with Commerce was 0.82. The correlation between average efficiencies for just the vertebrate and invertebrate categories between Millwood Lake and Neylandville was 0.87 and between Millwood Lake and Commerce, 0.72. These lowered correlations probably reflect basic differences due to different stratigraphic levels acting as the source of the fossils and to different depositional environments (lake beach gravels vs. stream gravels). For example, among the surface-collected fossils, Millwood Lake produced 39 echinoid plates and spines, no shark teeth, and no barracuda teeth compared to 4, 132, and 51 for the same categories from the Sulphur River sediments.

There is a correlation of 0.80 between amount of time spent surface collecting and number of vertebrates recovered throughout this study. There was much less correlation between time spent surface collecting to invertebrates produced (0.02) or to total fossils produced (0.35). On the other hand, correlation was low between total times for processing sediments from the individual squares and vertebrates recovered (0.17), invertebrates found (0.04), and total fossils found (0.05). In some circumstances a square would have an efficient yield by intensive processing, but one can not rely on high yields in any given square.

The range in richness of fossils in sediments observed in this study was considerable (2 to 72 vertebrates per square meter) but exceeded, for example, that of the Kansas Great Plains Pleistocene deposits. There, the standard procedure has been to search out sediments in which gastropod shells are readily visible (indicating past depositional conditions have not been so severe as to destroy delicate fossils) and then to collect the material in bulk, measured in fractions of tons, for concentration by water screening. In those circumstances, where stratigraphic considerations are of paramount importance, a quarry producing three mammalian teeth per 80-100 pound lot of sediment is regarded as a paying proposition. But in sediments as rich as were collected in this study, surface collecting is preferable over more intensive styles of processing.

SUMMARY

1. Surface collecting had 4.6 times the efficiency of intensive processing of sediments in terms of seconds per vertebrate fossil recovered.
2. More vertebrate fossils were found by surface collecting (319) than were recovered by laboratory processing (291).
3. Even from the standpoint of total fossils recovered, surface collecting produced 25% of the yield of laboratory processing or 68% of the lab yield if pelecypod shells are excluded.
4. Twenty-seven of the 28 taxa recognized in this study were recovered during surface collecting. The missing taxon is represented by only 1 specimen in the 6621 found in the laboratory.
5. Collecting efficiencies at all three sites had a correlation of 0.94, but in several aspects correlation between the South Sulphur River sites was higher than between either of them and the Millwood Lake locality.
6. There was a low correlation (0.05) between total processing time and total fossils found, but a high correlation (0.80) between time spent surface collecting and number of vertebrates recovered.

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MERMITHID NEMATODES: SEM OBSERVATIONS COMPARING HEXAMETHYLDISILAZANE AND CRITICAL POINT DRYING METHODS

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ABSTRACT

Morphological features of mermithid nematodes (Mermithidae) were studied with scanning electron microscopy, using hexamethyldisilazane-air drying in comparison with critical point drying via liquid carbon dioxide. Although general morphologic preservation of both HMDS-dried and CP-dried specimens was similar, structural features of the complex cuticle and internal organization were more easily resolved at higher magnifications in the HMDS-dried nematodes. These features include the superficial cuticular annulations, the fibrillar inner cuticle and peg-like microtrabeculae. The previously undescribed microtrabeculae are of special interest since they may facilitate an interaction of the mermithid (and perhaps nematodes in general) musculature with its body wall that, at least in part, may account for the unique thrashing locomotion so characteristic of these organisms.

INTRODUCTION

The scanning electron microscope (SEM) is a useful tool for elucidating morphologic aspects of nematodes for taxonomic studies. In preparing biological specimens for SEM, critical point (CP) drying has become the accepted standard for routine specimen drying for SEM observation (Postek, *et al.*, 1980). Eisenback (1986) compared several different techniques of preparing plant parasitic nematodes for SEM. These techniques included different fixatives in combination with different transitional fluids (liquid carbon dioxide or freon) for CP or freeze drying. He found that, for most nematode genera, glutaraldehyde fixation and freeze drying provided an adequate preservation of nematode morphology. Nation (1983), however, described another approch to specimen drying in which fixed dehydrated insects were immersed in hexamethyldisilazane (HMDS) and air dried. HMDS drying not only proved to be a satisfactory substitute for carbon dioxide critical point drying for insects, but bacteria as well (Giammara, *et al.*, 1987). HMDS drying significantly decreases the time required for specimen processing. The purpose of this study was to evaluate the applicability of HMDS drying to nematodes for SEM examination.

MATERIALS AND METHODS

Adult chironomids, host to parasitic imagocidal mermithid nematodes, were collected by light trapping at Lake Itasca, Minnesota, during the summer of 1989. Mermithids naturally emerged from their hosts in the laboratory. Isolated male and female specimens (Poinar, 1975; Johnson, personal communication), including post-parasitic larvae of an unidentified genus and of *Hydromermis,* and adults of *Lanceimermis,* were fixed in cacodylate buffered 2% glutaraldehyde for 4 days, postfixed in 1% osmium tetroxide for 30 min., and dehydrated in either an ethanol or acetone series. Acetone-dehydrated specimens were critical point dried using a Samdri 780A drier and liquid carbon dioxide as the transitional fluid. Alcohol-dehydrated specimens were immersed in HMDS for 10 min. and substantially air dried. Some specimens were also broken in half to allow study of internal features. The dried specimens were then mounted on stubs, coated with gold/palladium using a Hummer V sputter coater, and studied with an ISI DS-130 SEM using a LaB_6 electron source at an accelerating voltage of 10 kV.

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RESULTS AND DISCUSSION

COMPARISON OF HMDS- AND CP-DRIED MERMITHIDS

CPD-dried specimens of mermithids show most morphologic features characteristic of nematodes except that internal structural information was limited. The head of a CP-dried mermithid male shows such normal morphological features as cephalic papillae and mouth (Fig. 1). Shrinkage and distortion are evident in the head as well as body. Genital papillae and anal pore were also evident in CP-dried mermithid males. In both females and males, the superficial cuticular annulations (SCA) so clearly evident in transmission electron micrographs (TEM) of the body region (Batson, 1979; Poinar, 1983) are barely discernible in SEM micrographs of CP-dried specimens (Fig. 1). Cross-sectional views of CP-dried mermithids broken in two were badly fragmented and provided little information about the internal organization of these nematodes. Resolution of most structures was limited at magnifications above 4,000X.

Morphologic preservation of HMDS-dried mermithids was similar to that of CP-dried specimens except that cuticular detail and internal preservation were significantly better at higher magnifications. Although the head and body region of a HMDS-dried mermithid female in Fig. 2 exhibits some shrinkage, the specimen clearly shows the fine SCAs. The SCAs exhibit a parallel banding pattern in the body regions (Figs. 2, 3, 6). The pattern of SCAs in one mermithid species was distinctly regular (Figs. 2, 3), whereas in another it was highly irregular (Fig. 6). These initial observations suggest that SEM analysis of SCA patterns may have some taxonomic value for mermithid nematodes. In the head region, however, the pattern of SCAs becomes reoriented around the amphids so the SCAs now occur at right angles to those found in the body regions (Fig. 4) and form a circular pattern at the most anterior end (Fig. 2). Cross-sectional views of broken HMDS-dried mermithids were remarkably similar to that expected with freeze-fracture techniques. Fig. 5. shows the nematode trophosome with its numerous lipopro-

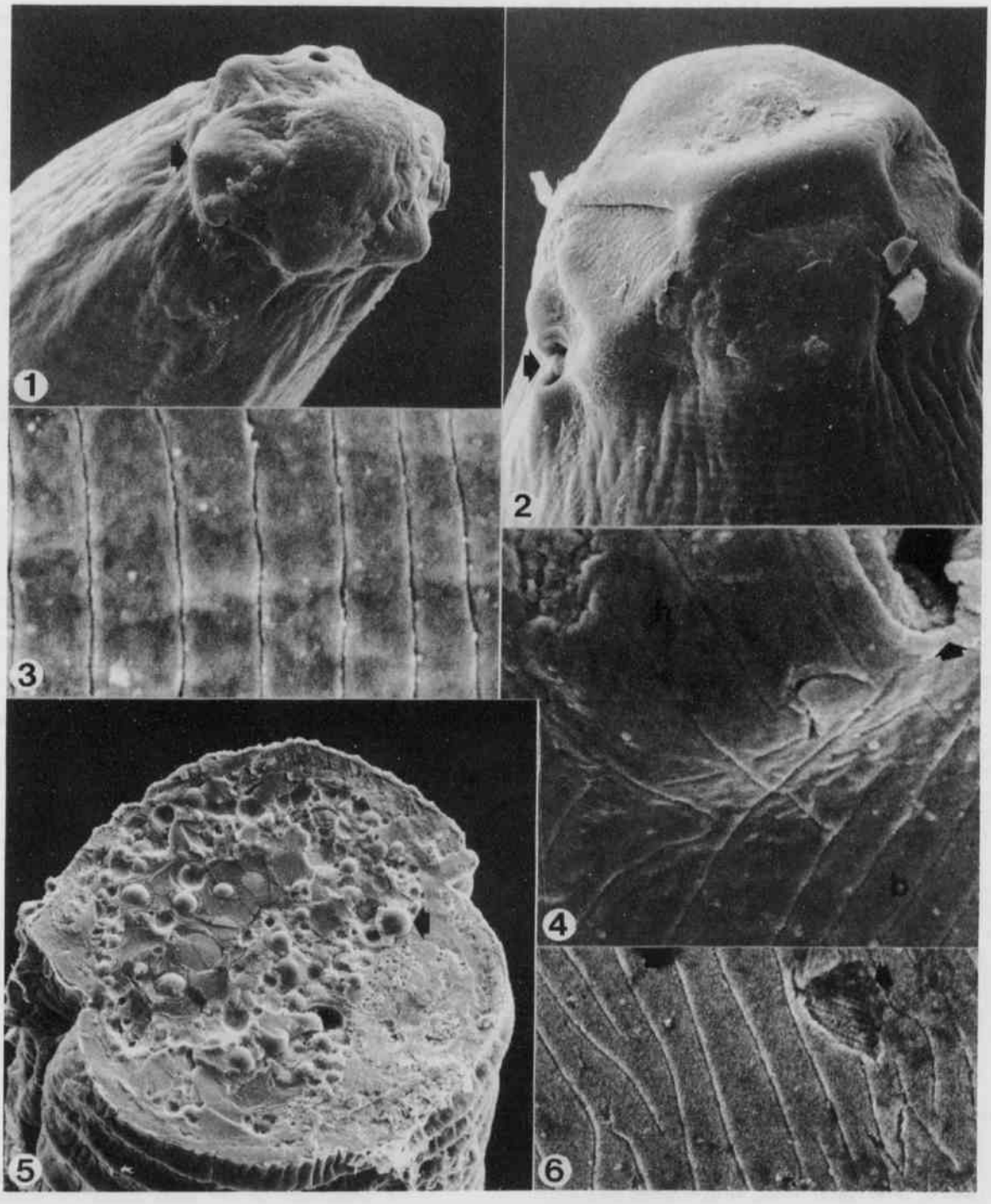

Figure 1. Head region of CP-dried *Lanceimermis* male, showing cephalic papillae (arrow) and mouth. 1,220X.
Figure 2. Head region of HMDS-dried mermithid female, showing amphid (arrow) and SCAs. 2,220X.
Figure 3. Body region of HMDS-dried mermithid, showing SCAs. 12,460X.
Figure 4. Head region of HMDS-dried mermithid, showing amphid (arrow) and transition of SCA orientation from body (b) to head (h) pattern. 13.170X.
Figure 5. Cross-sectional view of body of HMDS-dried *Hydromermis,* showing well-defined trophosome with numerous spherical lipoprotein globules (arrow). 786X.
Figure 6. Cuticle of HMDS-dried *Hydromermis,* showing exposed subcuticular fibers (arrow) and irregular SCA body pattern. 10,830X.

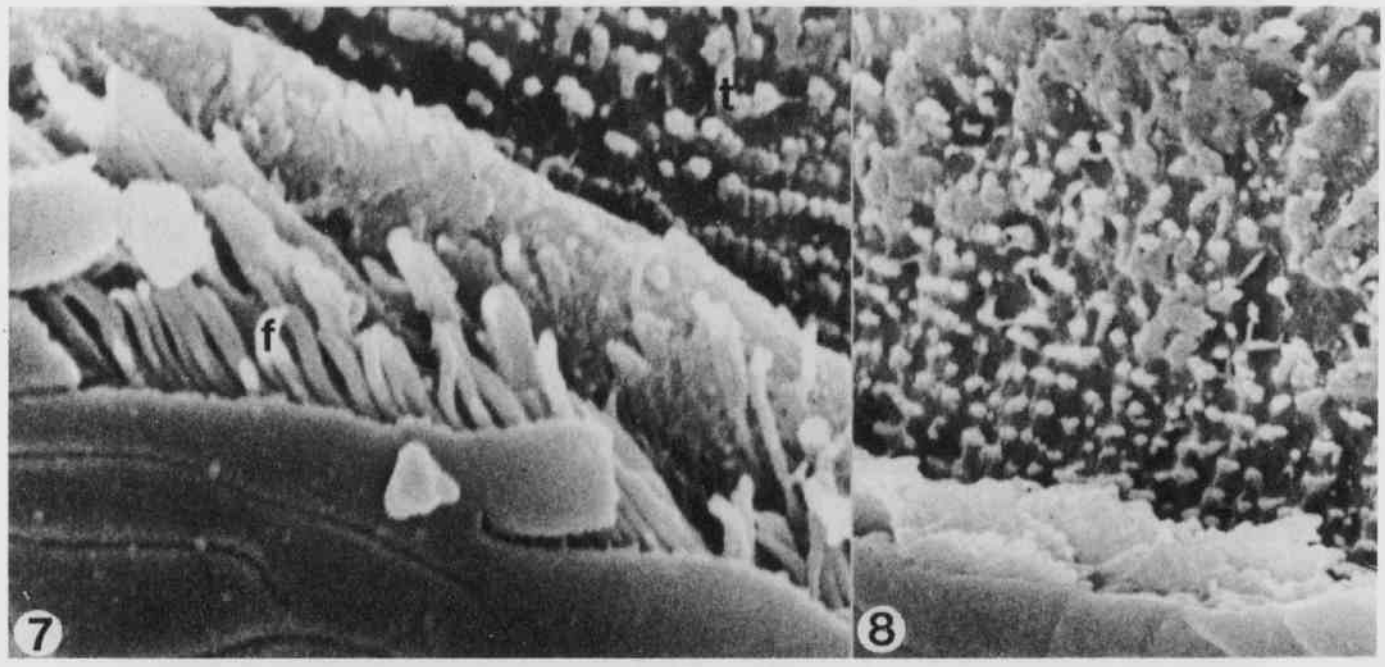

Figure 7. Torn outer body region of HMDS-dried *Hydromermis*, showing exposed fiber layers (f) of the cuticle and the numerous microtrabeculae (t) arranged in parallel series on the outer surface of a muscle band. 16,620X.

Figure 8. Same as Fig. 7, showing hypodermal remnants attached to microtrabeculae exposed beneath the cuticle. 11,400X.

tein globules as if it had been sections (Fig. 5). The unique muscle bands of the nematode were not distinct in this view. Torn cuticular surfaces of HMDS-dried mermithids (Figs. 6, 8), however, clearly demonstrated the 3-dimensional aspects of the inner fibrillar zone of the mermithid cuticle previously described by Batson (1979) from TEM micrographs. SEveral layers of fibers were evident, the individual fibers of which lie parallel one to another. All fiber layers together constituted an inner fiber belt oriented diagonally to the SCAs of the cuticle surface. Since the SCAs were perpendicular to the longitudinal axis of the nematode body, this fibrous belt is also oriented diagonally along the entire length of the nematode body.

Although general morphologic preservation of both HMDS-dried and CPD-dried specimens was similar, it is apparent that resolving the structural features of the complex cuticle and internal organization of mermithid nematodes with the scanning electron microscopy are best achieved with HMDS-dried specimens.

MICROTRABECULAE

Beneath the hypodermis, an elaborate system of minute peg-like structures covering the outer surface of the muscle bands were discovered in HMDS-dried mermithids (Figs. 7, 8). Since the presence of these structures has not been previously reported in the nematodes, including the mermithids (Batson, 1979; Poinar, 1983), we have termed these structures *microtrabeculae*.

These microtrabeculae project from the muscle surface toward the hypodermis of the body wall. They are arranged in parallel series perpendicular to the body wall and the longitudinal muscle bands (Figs. 7, 8). They appear to physically interact with the hypodermis, as suggested by tissue, presumably remnants of the hypodermis, that remains attached to some microtrabeculae (Fig. 8).

The functional role of the microtrabeculae is interesting and remains to be elucidated. The microtrabeculae however do appear to structually interact with the hypodermis (and therefore the cuticle and body wall). This could mean that they provide a structural means in which the mermithid's longitudinal musculature and body wall is integrated into a single biomechanical unit. If so, the microtrabeculae may then assume a major, previously unrecognized, role in the biomechanics of the thrashing locomotion so characteristic of the mermithids and perhaps nematodes in genera. Study of these structures and their relationship is being continued.

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ROTATIONAL SYMMETRIES OF NUCLEAR STATES: SPIN DETERMINATIONS IN ADVANCED LABORATORY

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ABSTRACT

An advanced laboratory experiment is described which shows the connection between the rotational symmetries of nuclear states and the assignments of spins to discrete nuclear states. Standard angular correlation methods were used to study the two sequential gamma ray transitions in each ^{60}Ni nucleus, populated by unobserved beta decays from a weak radioactive ^{60}Co source. The chosen electronics and detectors were inexpensive and easy to operate. This experiment was extended to introduce students to real-world data acquisition, using finite-geometry detectors, which resulted in enormously larger coincident data rates.

INTRODUCTION

Many advanced students in the physical sciences are introduced to the idea of the spin quantum number (J) of a state determining the symmetry of the state under spatial rotation (Brink and Satchler, 1968; Ferguson, 1965; Cramer and Eidson, 1964; Edmonds, 1960). However, this idea is rarely given a tangible counterpart in the laboratory. To correct this, a correlation experiment was sought, emphasizing clarity in experimental design while minimizing the need for expensive equipment.

The choice was narrowed to gamma-ray de-excitation of nuclear states, due to the large specific energies, resulting in very penetrating photons, thus, avoiding absorption corrections. Also, fairly small (7.62 cm x 7.62 cm) Sodium Iodide (NaI) detectors are fairly inexpensive, and their responses to gamma rays of wide energy range are well documented in the literature.

The experiment chosen was the measurement of angular correlations between two gamma rays, corresponding to sequential transitions in each ^{60}Ni nucleus, populated by unobserved beta decays from a weak radioactive ^{60}Co source. Figure 1 shows the decay scheme. Both

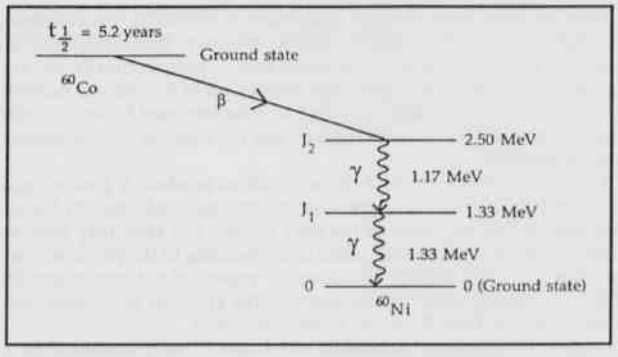

Figure 1. Decay scheme for radioactive ^{60}Co.

gamma rays are very penetrating, but have an average full-energy detection efficiency (peak-to-total ratio) of 36% in these small (7.62 cm x 7.62 cm) NaI detectors.

In this experiment, the second-excited state (spin = J_2) of ^{60}Ni decays by single gamma-ray emission to its first-excited state (spin = J_1) which decays by single gamma-ray emission to its ground state (spin = 0). The principal experimental goal was to distinguish between the different angular-correlation predictions for the two gamma rays, associated with different possible assignments of J_2 and J_1.

Eight distinct angular functions were calculated (Evans, 1955) for 11 different reasonable values for the nuclear spins: J_2 and J_1. Agreement between the angular correlation data and one of the predictions could provide unique assignments for J_2 and J_1, based on the expectation of a unique rotational symmetry associated with each of these discrete states (Brink and Satchler, 1968; Eisenbud and Wigner, 1958).

Perhaps as important for the student was the sense of "no guarantee" that the data would agree with any of these predictions, if there were some fundamental problem with quantum mechanics. The students showed anticipation in experimentally testing quantum mechanics by using its predictions in their attempt to extract spin quantum numbers.

Finally, students compared the situation of "point-geometry" predictions at distant detector settings with low counting rates to the situation of "finite geometry" predictions for close-in detector settings with much higher counting rates.

This comparison confronted students with experimental realities. They could take data with detectors at 20 cm, and come in every 12 hours to change angle (as they wanted statistical accuracy of 1%), or they could take data with detectors at 5 cm (at measured coincidence rates over 50 times as fast), and finish each run in 15 minutes. They could use the simple "point geometry" predictions at 20 cm, but they would have to make corrections in the predictions to compensate for "finite geometry" in the detectors at 5 cm.

Since the students had estimated in a rough calculation that the "finite geometry" correction was negligible at 20 cm, they decided, as an initial strategy, to set the detectors 20 cm from the source and read out the data about every 12 hours for 7 data points between 90 and 180 degrees, but taking 4 times longer at 90 degrees, so W(90°) would be well determined when forming the ratios: $W(\Theta)/W(90°)$.

Having established the spins, J_2 and J_1, using the point-geometry predictions, students decided to re-run the whole experiment at the 5 cm settings. New runs came in as fast as the students could plot their results. The anisotropy in each of the angular correlations was reduced, but students calculated new values for each candidate, and the spins were established in less than one-fiftieth of the 20-cm data-collection time.

The reason for re-doing the experiment was posed in more than 1 way. (1) With the spins established, re-doing the experiment allowed the student to check the accuracy of his finite-geometry corrections. (2) If this were an experiment being designed for a large accelerator facility, finite geometry work would be vital so as not to waste precious time on a very expensive machine. No Program Advisory Committee would tolerate point geometry with finite geometry measurements 50 times faster.

Students had no trouble viewing their work both ways. They realized the present apparatus as not expensive to run, and was not in high demand, so they were more comfortable in making their first com-

parisons without modifying the predictions for finite geometry. However, they understood the need to be able to make "real world" measurements, and they were quite amazed at the difference in data collection times.

MATERIALS AND METHODS

Figure 2 shows the point-geometry predictions for 11 different combinations of excited-state spins and de-excitation gamma ray multipolarities, the latter given in parentheses. It also shows results for data taken with the two 7.62 cm x 7.62 cm NaI detectors placed 20 cm from the source.

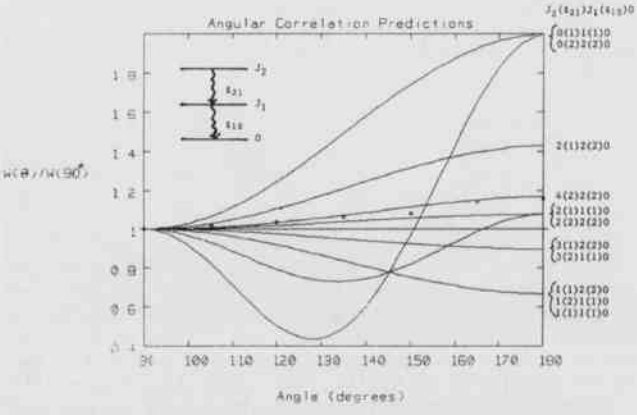

Figure 2. Predictions for eleven different combinations of excited state spins and de-excitation gamma ray multipolarities, the latter given in parenthesis. Data for ^{60}Ni are the small boxes.

The ^{60}Co source was a combination of 6 plastic disk sources, wrapped together to form a short cylinder, and placed equidistant from the two detectors: one being fixed at 0° and the other mounted on a movable arm. One percent statistical accuracy was intended, so 2 procedures were used to make systematic errors negligible.

A stick was cut as a template to assure the movable detector would be the same distance from the source, independent of angle. This procedure was carried out before any data acquisition, with the detector distances checked for angles between 90° and 180°. In addition, the cylindrical source was rotated, and the singles rates for the 1.33 MeV full-energy peak were measured to assure there was no favored orientation due to poor source positioning within the disks.

The half-life of the ^{60}Co is 5.2 years, so measurements taken over a 1 week interval could be normalized to clock time. The present sources add up to about 1 micro-Curie of activity, easily determined by singles measurements in either detector.

One of the 2 NaI detectors was equipped with a mu-metal shield on its photo-multiplier tube. This detector was used on the movable arm, so it would be insensitive to changes in the earth's magnetic field when placed in different orientations. Students appreciated the mu-metal shield when they observed the dramatic change in gain on the oscilloscope display of the singles pulses, when a small bar magnet (with a magnetic field much larger than the earth's field) was moved near the unshielded phototube, in contrast to the nearly negligible change in gain when the magnet was moved near the shielded phototube.

Figure 3 is a diagram of the electronics used to process linear energy signals from each NaI detector. The anode output of each phototube was sent through a voltage-sensitive, unit-gain preamplifier without changing its time response (about 10 nanoseconds rise time and 50 microseconds decay time).

The output of each preamplifier was sent to an RC shaping amplifier which produced a bipolar pulse whose crossover time is insensitive to the pulse height. Each bipolar linear energy signal was split into 2 paths: One was sent to a timing single channel analyzer (SCA) which required

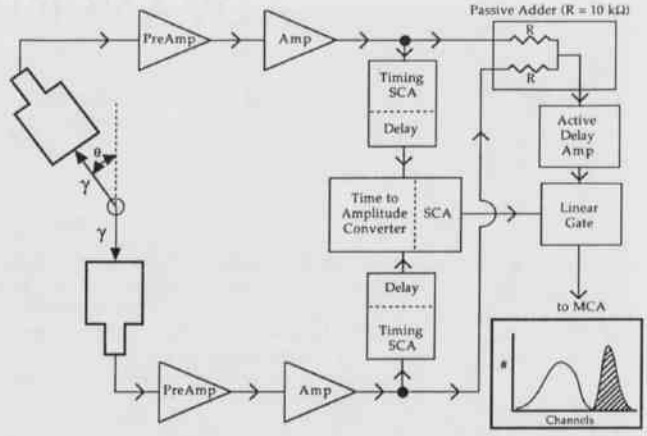

Figure 3. Electronics diagram for gamma-gamma coincidence using small Sodium Iodide detectors. SCA (single channel analyzer), MCA (multi channel analyzer).

the linear pulse to cross a lower threshold (but be less than an upper threshold) before a logic pulse was generated at the crossover time. The other signal was sent to a passive (resistive) mixer.

Each SCA output logic pulse was sent to an electronic unit to determine whether there were simultaneous signals present from both NaI detectors. This could have been accomplished using an overlap slow coincidence unit, but we chose to use a time-to-amplitude converter (TAC) with an internal timing single channel analyzer. The TAC provides the student a much clearer view of the coincidence process, as may be seen below.

The TAC produced a linear signal proportional to the difference in time between the 2 logic signals from the 2 SCAs, where the latter were separated by an artificial delay of about 100 nanoseconds, set using the internal delays of the SCAs.

The TAC linear output could be inhibited using its internal SCA, so both upper and lower gates could be set around the "true" coincidence time peak, which sat above a very small (but observable) accidental background. The upper and lower SCA gates of the TAC were set with 10-turn helipots, and their positions were calibrated by measuring their effect on the TAC linear signal, initially sent (for calibration purposes) to a multichannel analyzer (MCA).

The amplitude of each linear signal sent to the MCA was converted to a digital value by its analog-to-digital converter. The horizontal scale displayed channel numbers, corresponding to monotonically increasing values of the digitized signal. The population of the channel number, corresponding to each digitized pulse, was incremented by one for each pulse processed. The vertical display was the readout of this population per channel.

The SCA helipots of the TAC were set to produce a gating signal for a time difference corresponding to the time peak (due to "true" coincidences) during most of the data taking. But later they were set to produce a gating signal for pulses corresponding to the very low counting rate (flat distribution) "accidental" region of the time spectrum, allowing a quantitative measurement of the effect of accidental coincidences on the final $E_1 + E_2$ coincidence data.

Using this technique, accidental coincidences were measured to be less than 2%. This meant they could be ignored, since accidental rates only affect the anisotropy [W(Θ)/W(90°) - 1]. A 1% measurement of the yield ratio means determining a 16% anisotropy to 6% (and a 10% anisotropy to 10%), so the effect of accidentals on the anisotropy is less than the statistical error.

The internal SCA of the TAC was used to generate the gating signal for the linear gate, which passed pulses from the mixer only when a true coincidence was present. This device took about 2 microseconds to make this electronic decision, so the output of the passive mixer was routed through an active delay amplifier, which produced a delayed linear output.

The delayed signal from the mixer was sent to the linear gate. When an SCA logic pulse from the TAC was present, the linear gate opened, permitting the linear pulse to pass. This only occurred when there were simultaneous signals present from both detectors. The mixer signal was passed through the linear gate only when signals from both detectors were present. Thus, the mixer operated as a linear adder of each detector's linear energy signal, so the output of the linear gate was proportional to $E_1 + E_2$, when the gains of the two detectors were matched.

Figure 4 is an example of a gamma-ray "singles" spectrum, taken with either NaI detector. The vertical population index was incremented for the horizontal scale corresponding to energy deposition in the detector, for each singles event. The 2 sharp peaks correspond to full-energy deposition of 1.17 MeV and 1.33 MeV gamma rays, arriving asynchronously, in each detector.

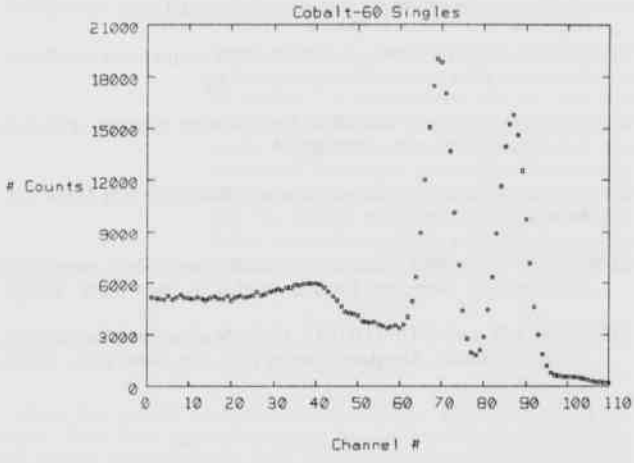

Figure 4. Gamma ray singles from either small NaI detector.

Each full-energy peak was separated from the most energetic Compton scattering for that gamma ray. Thus, when there was a true coincidence between the 2 detectors, and each detector measured the full-energy of the gamma ray, the sum peak had the fixed value of: $E_{sum} = E_1 + E_2 = 1.17$ MeV + 1.33 MeV = 2.50 MeV. If 1 of the detectors had full-energy deposition while the other had a Compton scattering, the event was processed in the spectral region below the sum energy peak. Figure 5 is a sum energy spectrum, formed with the linear gate opened only for true coincidences. The sum energy peak is well resolved on the right, where the broad spectrum on the left was incremented if one or both of the gamma rays escaped (not yielding full energy).

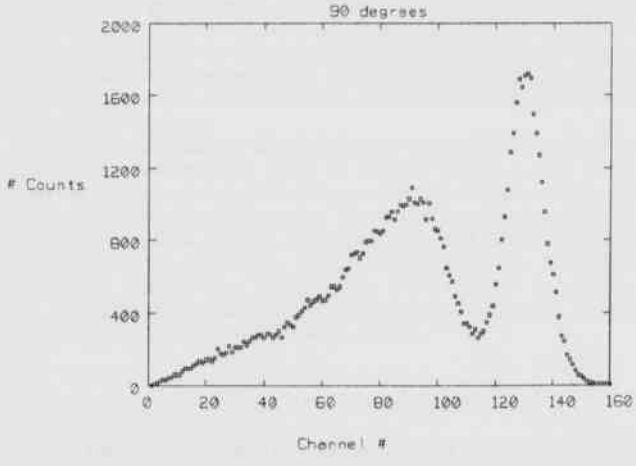

Figure 5. Coincidence gamma-gamma sum spectrum for ^{60}Ni.

Gain matching between the 2 detectors was carried out using the MCA and a slight (temporary) modification in the electronics. For each detector, the positive logic output of each SCA was used to open the linear gate, so the mixed signal passed would come from only 1 of the detectors, depending on which SCA was being used to open the linear gate.

Once the gain of one of the detectors was adjusted to give a suitable display in the MCA, the other SCA was used to open the linear gate, passing the singles pulses from the other detector. The amplifier gain was adjusted until the centroids of the 1.17 MeV and the 1.33 MeV peaks agreed within 0.3 channels of those in the first detector. A gaussian fitting routine in the computer based MCA was used to determine these centroids, but the use of overlap spectra (usually available in MCAs) works about as well in matching the relative gains.

Since the statistical error was chosen to be less than 1% in determining the ratio of W(Θ)/W(90°), systematic errors must be kept below 1% also. Thus, the method for determining the number of counts in the sum energy peak was examined, since extracting peak areas to better than 1% accuracy is not a trivial feat. Fortunately, only the ratios N(Θ)/N(90°) were needed to better than 1%. This should be assured if each area (both numerator and denominator) were determined in a consistent way, as each Compton background was nearly proportional to the sum peak area. In order to be able to test for consistency in determining each ratio, 2 different methods were used: summing the populations within the sum peak and fitting the sum peak to a gaussian.

Both methods impressed the students with the need for gridding the sum peak over many channels (20 or more) for both methods of peak extraction: (1) so the error in the summing technique would not sensitively depend on the cutoff channels, and (2) so the gaussian fitting procedure would have enough data points to allow the extraction of a reliable area.

Had they demanded less statistical accuracy, the students would have missed the opportunity to overcome the systematic difficulties in extracting peak areas. Also, their determination of spins would have been less certain. Having faced and overcome these problems, the students seemed proud of their newly acquired experimental skills.

RESULTS

The data points in Figure 2 are to be compared with the point geometry predictions of the various candidate angular correlation functions. A similar graph for finite geometry could have been included, but it differs very little from Figure. 2, except the anisotropies are smaller (like a squeezed accordion).

Correcting the predicted angular correlation functions for the finite geometry of the gamma-ray detectors was accomplished easily when the correlation functions are written as $W(\Theta) = a_o + A_2P_2(\cos\Theta) + a_4P_4(\cos\Theta) + a_4P_4(\cos\Theta)$, where the P_{2L} functions are the ordinary Legendre polynomials. Published correction factors for the a_{2L} coefficients are available (Marion and Young, 1968). For the 5 cm positions, each a_2 is reduced by the factor 0.6496 and each a_4 is reduced by the factor 0.2116.

The source of the 11 different angular correlation functions (Evans, 1955) listed them as $W(\Theta) = b_0 + b_2\cos^2\Theta + b_4\cos^4\Theta$. Because of this, it is convenient to be able to relate each set of a_{2L} coefficients to the b_{2L} coefficients: $a_4 = (8/35)\, b_4$, $a_2 = (4/7)\, b_4 + (2/3)\, b_2$, and $a_o = (1/5)\, b_4 + (1/3)\, b_2 + b_o$, using the orthogonality properties of Legendre polynomials (Boas, 1983).

As an example, using the 4(2)2(2)0 transitions, finite geometry corrections for the ratio R = W(180°)/W(90°) give the following values: (1) For detectors 20 cm from the ^{60}Co source, R = 1.159, instead of 1.167 for point geometry, and (2) For detectors 5 cm from the ^{60}Co source, R = 1.103.

DISCUSSION

Students showed interest in the idea of connecting rotational symmetry properties of nuclear states to measured angular correlation functions, as determined by the spin quantum numbers of these states. They seemed most comfortable with references (e.g., Cramer and Eidson,1964) using the rotation matrix to calculate the angular correlations directly, as they could see the connection between the spin quantum number in the rotation matrix and the angular dependence of the rotation matrix. This may have been due in part to their seeing plots of the rotation matrices (Cramer and Braithwaite, 1972), as well as the connection between simple rotation matrices and Legendre polynomials (Braithwaite, 1973; Braithwaite and Cramer, 1972).

Students seemed to find this a particularly enjoyable lab, despite the considerable effort it required of them.

ACKNOWLEDGMENT

Thanks are extended to Dr. Richard Prior for his suggestion of using ^{60}Co in conjunction with the published list of 11 candidate angular correlation functions (Evans, 1955). Also, thanks are extended to Dr. Andre' Rollefson for his suggestion of incorporating the finite geometry measurements into this laboratory experiment, and for his many helpful comments during the writing of this manuscript.

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THE AQUATIC MACROINVERTEBRATES OF THE ST. FRANCIS SUNKEN LANDS IN NORTHEAST ARKANSAS

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ABSTRACT

The primary objective of this study was to survey the aquatic macroinvertebrate diversity of the St. Francis Sunken Lands in northeast Arkansas. Secondary objectives were a determination of their relative abundance and distributional and seasonal patterns. Sixty semi-annual collections were made from 30 stations by sampling each station 2 times for 1½ man-hours with a Turtox Indestructible™ dip net. Totals of 243 taxa and 13,952 organisms were recorded for the sample period (August 1987-July 1988). Each station was assigned to 1 of 4 associations, distinguished by distinct physical factors within the river channels and the immediate watershed. The Old River Channel-Oxbow Association exhibited the most complex and stable community structures; this was attributed to the relative lack of man's alteration of the habitat. The Channelized Ditches-Point Source Pollution Association demonstrated obvious detrimental effects of man's intervention. The relatively simple community structures of the St. Francis Lake-Open Water Association were attributed to the typically homogeneous substrates of this area. The simplest community structures were in the Channelized Ditches-Intense Agriculture Association and were a direct result of man's multiple alterations within the river channels and immediate watershed. Seasonal species diversity indices and numbers of taxa varied inversely with respect to water level. High values occurred during low-water periods, whereas lower values occurred during high-water periods. This inverse relationship was attributed to flooded habitat, which led to population dilution and diminished collecting success.

INTRODUCTION

Along the eastern edge of Crowley's Ridge, within the upper St. Francis River flood plain of Arkansas, lies a rather unique physiographic area known as the Sunken Lands. Beginning at the Arkansas-Missouri state line in eastern Greene County, the Sunken Lands follow the St. Francis River's braided pattern of oxbows, sloughs, channels and ditches. Meandering southward through Craighead County and into Poinsett County, this braided reach of the river consolidates at the lower end of the Sunken Lands, in the vicinity of Marked Tree. Ranging in width from 1.0-7.5 km, the Sunken Lands extend approximately 50.0 km longitudinally (Fig. 1). Surface gradients range from 0-3% and elevation ranges from 71.6-64.0 m above sea level. The soil type of the watershed is fine-grained alluvial silt, sand and clay sediment; the substrates vary from firm mud or sand to deposits of silt and/or organic detritus (Saucier, 1974). Mean annual rainfall is 126.6 cm; mean annual temperature is 15.9° C (U.S. Dept. of Comm. Nat. Oceanic and Atm. Adm., 1987, 1988). Characterized by seasonally-flooded bottomland hardwood and agriculturally inhospitable terrain, the Sunken Lands offer a natural refugium for flora and fauna which were perhaps more broadly distributed in the Mississippi Alluvial Plain before man's alteration of habitat became so severe. Present utilization of the aquatic natural resources is limited primarily to commercial fishing, sport fishing and waterfowl hunting.

The primary purpose of this study was to survey the diversity of the aquatic macroinvertebrates of the St. Francis Sunken Lands. Determination of their relative abundance and distributional and seasonal patterns were secondary objectives. The mussel community of the St. Francis River system has been extensively surveyed (Meek, 1896; van der Schalie and van der Schalie, 1950; Stansbery and Stein, 1982; Bates and Dennis, 1983; Clarke, 1985; Harris, 1986; Ahlstedt and Jenkinson, 1987a, b). Comprehensive investigations of any other aquatic macroinvertebrate communities were lacking.

METHODS AND MATERIALS

Thirty stations were established throughout the Sunken Lands (Fig. 1). Two samples were collected from each station at 6 month intervals for a total of 60 samples (August 1987-July 1988). Each sample consisted of 1½ man hours with a Turtox Indestructible™ dip net, and

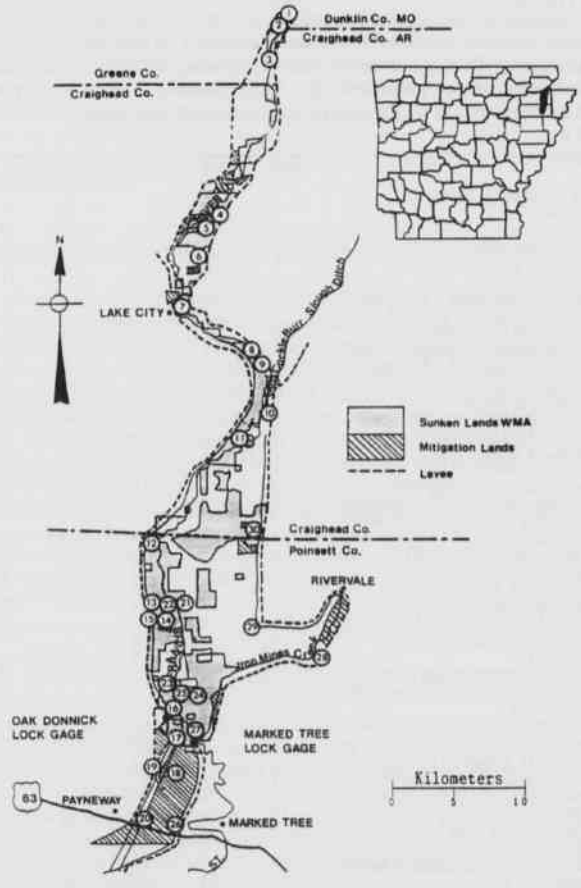

Figure 1. Study area and station locations.

specimens were preserved in 70% ETOH. Mussel relics were collected by hand. The specimens were identified in the laboratory, cataloged and placed in the Aquatic Macroinvertebrate Collection of the Arkansas State University Museum of Zoology (ASUMZ) as voucher specimens. General identifications were made using keys by Pennak (1978) and Merritt and Cummins (1984). Keys used for specific determinations are Hungerford (1923), Drake and Chapman (1953), Young (1954), Wilson (1958), Froeschner (1962), Wooldridge (1966), Zimmerman (1970), Gousoulin (1973 & 1975), Tarter, Watkins and Little (1976), Gunderson (1978), Pennak (1978), Schuster and Etnier (1978), Hilsenhoff (1980), Kittle (1980), Pescador and Berner (1981), Merritt and Cummins (1984), and Young (1985).

Shannon-Wiener Diversity (H'), Simpson Diversity, Simpson Dominance, H'max and Evenness values were calculated at base 2 logarithm using the AQUATIC ECOLOGY-PC program of Oakleaf Systems, Decorah, IA (Cochran, 1990). Calculated diversity indices maintained strikingly similar longitudinal, as well as seasonal patterns, therefore H' is used representively in this report. H' represents the absolute diversity or the average degree of uncertainty of predicting the species of a given individual selected at random from a population (Schemnitz, 1980).

RESULTS AND DISCUSSION

A total of 13,952 organisms constituting 243 taxa was collected. Seventy-eight percent were Insecta, consisting of Coleoptera (33%), Hemiptera (20%), Odonata (12%), Diptera (10%), Ephemeroptera and Trichoptera (9% each), Collembola (4%), and Plecoptera and Megaloptera (1.5% each). Other taxa, listed in order of decreasing abundance, were Mollusca (11% of the total taxa), Crustacea (6%), Annelida (4%) and Turbellaria, Nematoda and Nematomorpha at <1% each (Table 1).

Table 1. Aquatic macroinvertebrates expressed as number collected/association (OROA, old river channel-oxbow; CDPA, channelized ditches-point source pollution; SFLA, St. Francis' Lake-open water; CDAA, channelized ditches-intense agriculture) and study area total (SAT).

	OROA	CDPA	SFLA	CDAA	SAT
Cura foremanii (Girard)	.	.	.	1	1
Nematoda	4	1	.	1	6
Gordius spp.	.	.	.	2	2
Paragordius spp.	1	1	.	.	2
Ferrissia rivularis (Say)	5	9	1	4	19
Fossaria obrussa (Say)	3	.	.	8	11
Laevapex diaphanus (Haldeman)	.	.	1	1	2
Menetus dilatatus (Gould)	9	3	6	7	25
Physella gyrina (Say)	92	3	42	34	171
Pseudosuccinea columella (Say)	.	1	2	.	3
Corbicula fluminea (Müller)	31	2	1	2	36
Amblema plicata ssp.	.	4	.	.	4
Anodonta grandis Say	1	.	5	.	6
A. imbecillis Say	7	.	.	.	7
A. suborbiculata Say	1	.	3	.	4
Lampsilis ovata (Say)	1	1	.	.	2
L. teres (Rafinesque)	.	.	1	1	2
Lasmigona complanata ssp.	.	1	.	.	1
Leptodea fragilis (Rafinesque)	7	1	.	.	8
Obliquaria reflexa Rafinesque	.	.	1	.	1
Potamilus capax (Green)	.	.	.	1	1
P. purpuratus (Lamarck)	.	.	.	2	2
Quadrula pustulosa ssp.	.	1	1	.	2
Q. quadrula (Rafinesque)	.	2	2	.	4
Toxolasma parva (Barnes)	17	.	4	1	22
Truncilla truncata Rafinesque	.	1	.	.	1
Uniomerus declivis (Say)	.	.	5	.	5
Sphaeriidae	36	.	6	12	54
Musculium transversum (Say)	2	.	.	.	2
Sphaerium striatinum (Lamarck)	2	.	.	.	2
Oligochaeta	33	3	10	81	127
Naididae	.	.	1	.	1
Branchiobdellida	1	.	23	.	24
Helobdella stagnalis (L.)	.	3	1	1	5
H. triserialis (Blanchard)	1	.	.	2	3
Placobdella sp.	.	1	.	.	1
P. ornata (Verrill)	5	.	4	1	10
P. parasitica (Say)	.	.	.	1	1
Argulus sp.	.	.	.	4	4
Taphromysis louisianae Banner	2	20	1	.	23
Caecidotea spp.	160	34	230	44	468
Lirceus spp.	1354	.	290	18	1662
Crangonyx spp.	380	45	138	81	644
Gammarus fasciatus Say	37	35	57	104	233
Hyalella azteca (Saussure)	5	1	8	14	28
Cambarellus (Pandicambarus) shufeldtii (Faxon)	26	.	82	4	112
Cambarus (Lacunicambarus) sp.	1	14	.	4	19
Orconectes (Buannulifictus) palmeri palmeri (Faxon)	27	1	3	3	34
O. (Traqulicambarus) lancifer (Hagen)	5	.	12	1	18
Procambarus (Ortmannicus) acutus acutus (Girard)	9	1	.	4	14
P. (Scapulicambarus) clarkii (Girard)	30	1	5	6	42
Palaemonetes kadiakensis Rathbun	887	93	85	622	1687
Unionicola sp.	1	.	.	.	1
Entomobrya sp.	.	.	.	2	2
Hypogastruridae	1	.	.	.	1
Odontella sp.	.	2050	.	.	2050
Isotomidae	.	.	.	80	80
Isotomurus sp.	1	.	.	.	1
Podura aquatica L.	.	.	.	1	1
Sminthuridae	.	1	.	.	1
Baetidae	1	.	.	1	2
Baetis spp.	23	52	3	22	100
B. intercalaris McDunnough	5	.	.	.	5
Callibaetis fluctuans (Walsh)	1	.	.	.	1
Pseudocloeon sp.	1	1	.	.	2
Baetisca obesa (Say)	7	.	.	5	12
Caenis spp.	101	2	71	25	199
Ephemerellidae	1	.	.	.	1
Hexagenia limbata (Serville)	80	8	23	27	138
Pentagenia vittigera (Walsh)	.	.	.	1	1
Stenacron interpunctatum Say	.	2	.	2	4
Stenonema exiguum Traver	2	.	.	.	2
S. mediopunctatum (McDunnough)	4	.	.	.	4
S. pulchellum (Walsh)	1	.	.	.	1
Isonychia spp.	61	3	.	4	68
Tricorythodes atratus (McDunnough)	3	2	.	.	5
Hetacrina spp.	74	.	.	.	74
Coenagrionidae	.	.	1	1	2
Argia spp.	95	31	5	85	216
A. apicalis (Say)	.	.	.	54	54
Enallagma spp.	64	2	6	27	99
Ischnura spp.	.	.	21	6	27
Dromogomphus spinosus Selys	6	.	.	.	6
D. spoliatus Hagen	56	.	.	5	61
Gomphus sp.	.	1	.	.	1
G. (Arigomphus) lentulus Needham	29	.	8	.	37
G. (A.) submedianus Williamson	1	.	.	.	1
G. (Gomphurus) vastus Walsh	.	.	.	1	1
G. (Stylurus) ivae Williamson	1	.	.	.	1
G. (S.) plagiatus Selys	13	2	.	1	16
Boyeria vinosa Say	3	.	.	.	3
Nasiaeschna pentacantha Rambur	10	.	.	2	12
Macromia spp.	30	.	.	6	36
Epicordulia princeps (Hagen)	46	.	1	.	47
Neurocordulia molesta Walsh	3	1	.	.	4
Tetragoneuria cynosura (Say)	40	.	.	.	40
Libellula spp.	7	.	.	2	9
Perithemis tenera Say	17	.	1	1	19
Plathemis lydia Drury	.	.	.	3	3
Prostoia sp.	8	.	.	8	16
Perlesta spp.	74	22	.	4	100
Isoperla spp.	60	.	.	5	65
Belostoma flumineum Say	.	.	2	.	2
B. lutarium (Stal)	2	.	.	.	2
Corisella inscripta (Uhler)	.	.	.	1	1
Corixidae (nymphs)	24	.	51	101	176
Hesperocorixa nitida (Fieb.)	.	1	.	1	2
Palmacorixa buenoi Abbot	15	1	4	23	43
Trichocorixa kanza Sailer	15	15	123	625	778
Gelastocoris oculatus oculatus (Fab.)	9	4	.	3	16
Gerridae sp. (nymph)	.	.	1	.	1
Limnoporus sp. (nymphs)	2	.	1	3	6
L. canaliculatus (Say)	20	10	6	23	59
Metrobates alacris Drake	3	.	.	.	3
Neogerris hesione (Kirkaldy)	1	.	.	1	2
Rheumatobates sp.	.	.	.	2	2
R. hungerfordi Wiley	.	.	.	2	2
R. palosi Blatchley	.	.	.	2	2
R. tenuipes Meinert	13	.	2	32	47
R. trulliger Bergroth	.	.	.	1	1
Trepobates spp. (nymphs)	.	.	.	4	4
T. knighti Drake and Harris	.	.	.	4	4
T. subnitidus Esaki	2	.	9	54	65
Hebrus burmeisteri Lethierry and Severin	.	.	.	2	2
H. consolidus Uhler	1	.	.	.	1
Hydrometra martini Kirkaldy	41	2	.	6	49
Mesovelia sp.	.	.	.	3	3
M. mulsanti White	1	.	.	4	5
Ranatra australis Hungerford	.	.	.	1	1
R. buenoi Hungerford	1	.	.	2	3
Notonecta indica Linnaeus	.	.	.	1	1
N. irrorata Uhler	2	.	1	.	3

Table 1. Cont.	OROA	CDPA	SFLA	CDAA	SAT
Neoplea striola Fieber	.	.	.	1	1
Saldidae	.	.	.	3	3
Salda sp.	5	.	.	.	5
Saldula sp.	1	.	.	.	1
Microvelia sp.	.	.	.	1	1
M. hinei Drake	1	.	1	.	2
Paravelia sp.	.	.	1	.	1
Rhagovelia spp.	45	.	.	2	47
R. knighti Drake and Harris	25	2	.	.	27
Chauliodes rastricornis Rambur	.	.	.	3	3
Corydalus cornutus Linnaeus	6	.	.	1	7
Sialis Latreille	46	1	2	4	53
Brachycentrus sp.	1	.	.	.	1
B. numerosus (Say)	1	.	.	.	1
Cheumatopsyche spp.	26	1	.	.	27
Hydropsyche spp.	33	.	.	1	34
H. bidens Ross	3	7	.	.	10
H. hageni Banks	2	.	.	.	2
H. incommoda Hagen or H. simulans Ross	26	1	.	.	27
Macronema carolina Banks	47	2	.	.	49
M. zebratum (Hagen)	.	3	.	.	3
Hydroptila spp.	1	.	1	.	2
Neotrichia sp.	1	.	.	.	1
Orthotrichia spp.	1	.	7	1	9
Ironoquia spp.	3	.	.	1	4
Ceraclea sp.	1	.	.	.	1
Nectopsyche spp.	21	2	.	20	43
Oecetis spp.	.	.	2	.	2
Ptilostomis sp.	5	.	.	.	5
Neureclipsis spp.	5	.	.	.	5
Chlaenius sp.	.	.	.	1	1
Bagous spp.	.	.	.	29	29
Hyperodes sp.	.	.	.	1	1
Lixus spp.	.	.	.	30	30
Agabus disintegratus (Crotch)	1	.	.	.	1
Bidessonotus inconspicuus (LeConte)	.	.	.	31	31
B. longovalis (Blatchley)	5	.	.	.	5
Copelatus chevrolati renovatus Guignot	2	.	.	.	2
C. glyphicus (Say)	.	.	.	1	1
Coptotomus sp. (larvae)	3	.	.	.	3
C. venustus (Say)	56	3	4	38	101
Hydaticus sp.	2	.	.	.	2
Hydroporus spp. (larvae)	2	.	.	1	3
Hydroporus spp.	216	12	39	111	378
Laccophilus fasciatus rufus Melsheimer	3	.	.	1	4
L. proximus proximus Say	35	2	.	27	64
Liodessus sp.	1	.	.	.	1
Lioporius pilatei (Fall)	136	.	12	4	152
L. triangularis Fall	2	.	.	.	2
Oreodytes spp. (larvae)	17	.	.	2	19
Thermonectus basillaris (Harris)	5	4	1	12	22
Uvarus spp.	65	10	3	38	116
Ancyronyx variegata (Germar)	.	.	.	1	1
Dubiraphia spp. (larvae)	6	2	.	1	9
D. vittata (Melsheimer)	3	.	.	6	9
Macronychus glabratus Say	24	2	.	4	30
Ordobrevia sp. (larva)	.	.	.	2	2
Stenelmis spp. (larvae)	12	1	.	1	14
S. crenata (Say)	10	.	.	.	10
S. decorata Sanderson	.	.	.	8	8
Dineutus spp. (larvae)	.	.	.	3	3
D. assimilis (Kirby)	82	.	4	20	106
D. emarginatus (Say)	.	.	.	3	3
Gyretes spp.	.	1	.	72	73
Gyrinus spp.	158	.	.	11	169
Haliplus spp.	3	2	1	22	28
Peltodytes dunavani Young	2	.	.	4	6
P. sexmaculatus Roberts	20	15	7	124	166
Berosus spp. (larvae)	.	.	1	2	3
Berosus spp.	14	1	9	104	128
Crenitis sp.	.	.	.	1	1
Enochrus blatchleyi (Fall)	1	1	.	5	7
E. ochraceus (Melsheimer)	7	1	.	12	20
E. pygmaeus nebulosus (Say)	2	.	.	1	3
E. sayi Gundersen	.	.	.	1	1
Helochares sp. (larva)	.	.	.	1	1
H. maculicollis Mulsanti	5	.	.	2	7
Helophorus spp.	15	3	1	115	134
Hydrobiomorpha casta (Say)	.	.	.	1	1
Hydrobius sp.	1	.	.	.	1
Hydrochus spp.	3	.	1	5	9
Laccobius sp.	.	.	.	4	4
Paracymus confluens Wooldridge	6	.	.	.	6
P. subcupreus (Say)	3	.	.	1	4
Tropisternus spp. (larvae)	2	1	.	.	3
T. blatchleyi blatchleyi D'Orch.	3	.	.	.	3
T. lateralis nimbatus (Say)	68	5	.	71	144
T. collaris striolatus (LeConte)	3	.	.	.	3
Hydrocanthus atripennis Say	1	.	.	4	5

Table 1. Cont.	OROA	CDPA	SFLA	CDAA	SAT
Suphisellus bicolor bicolor (Say)	.	.	.	3	3
Cyphon spp. (larvae)	4	.	1	9	14
Cyphon spp.	4	.	2	4	10
Ceratopogonidae	7	2	12	6	27
Dasyhelea spp.	6	.	3	10	19
Stilobezzia spp.	7	.	3	1	11
Chaoborus sp.	.	.	.	2	2
Chironomidae	460	10	52	231	753
Tanypodinae	1	.	.	.	1
Tanytarsini	.	.	1	.	1
Culicidae	.	.	.	2	2
Dolichopodidae	.	2	.	.	2
Empididae	1	.	1	2	4
Sciomyzidae	.	.	.	1	1
Sepedon sp.	2	.	1	.	3
Simulium spp.	67	.	.	.	67
Chrysops sp.	1	.	.	.	1
Tabanus sp.	1	.	.	.	1
Tipulidae	4	.	.	2	6
Erioptera sp.	.	3	.	.	3
Limonia sp.	.	.	.	1	1
Tipula spp.	1	5	.	16	22
Total Individuals	6184	2603	1544	3621	13952
Total Taxa	164	78	78	154	243

The mean number and range of taxa/station for the study area were 23 and 5-59, respectively. THe mean number and range of individuals/station were 233 and 62-1115, respectively. The mean and range of H'/station for the study area were 2.962 and 1.751-4.704, respectively.

Because of the multiple variables exerting diverse influences within the Sunken Lands, the patterns of aquatic macroinvertebrate abundance, diversity and distribution were complex. Physical variables of the study area included the old river channels, oxbows, channelized ditches, open water, substrates and current. External influences included diverse soils and vegetation of the watershed, seasonal variation, point-source and non point-source pollution. To properly evaluate each station, the mean number of taxa, individuals, and diversity index for initial and revisit collections were used to predict the soundness or stability of the community status. Similarities that emerged within the study area were longitudinal and were associated with physical characteristics and external influences.

OLD RIVER CHANNEL-OXBOW ASSOCIATION (OROA)

These stations (1-5, 8, 9, 11, 12 and 15) possessed the greatest diversity values, greatest wealth of taxa and the largest mean numbers of individuals per station. They were located in the upper region of the study area where the watershed typically contained climax vegetation of cypress, oaks and willows (Fig. 1). Man's influence was limited for the most part to duck blinds and trotlines. The mean number of taxa/station was 18% greater than that for the entire study area, while the mean number of individuals/station was 25% greater, and the mean H' value was 4% greater (Table 2). Stations of this association exhibited the greatest heterogeneity of aquatic macroinvertebrates within the study

Table 2. Mean number of taxa, individuals and H' per station for each association and study area (SA).

	OROA	CDPA	SFLA	CDAA	SA
Taxa	28	30	17	19	23
Individuals	310	1115	155	138	233
H'	3.066	2.939	2.843	2.933	2.962

area. The turbidity levels were markedly lower than in any of the other associations and ranged from almost clear to only moderately turbid. Sixty-seven percent of the total individuals and 50% of the pelecypod taxa were collected from these stations. Considered scarce, *Toxolasma parva* was collected almost exclusively in this association. Of the Ephemeroptera occurring within the study area, 53% of the total individuals and 88% of the taxa were collected here. Eighty percent of the plecopterans captured in this study, as well as 66% of the trichopteran individuals, and 89% of the total taxa were found in this association. Odonates were well represented by 73% of the total in-

dividuals and 74% of the total taxa. The anisopteran odonates were more numerous than the zygopterans, and gomphids dominated the taxa. Of the dipterans, 61% of the chironomids were collected in this association and *Simulium* spp. were only taken within these stations (Table 1).

CHANNELIZED DITCHES-POINT SOURCE POLLUTION ASSOCIATION (CDPA)

There were only 2 stations in this association (13 and 16). Furthermore, diversity indices were biased by a large number (2050) of *Odontella* sp. collected on one date (Tables 1 and 2). For these reasons, this association is not discussed further.

ST. FRANCIS LAKE-OPEN WATER ASSOCIATION (SFLA)

These stations (21-25) occurred in relatively undisturbed areas. The mean number of taxa/station was the least for any association, 26% less than the mean for the entire study area and 40% less than that for the OROA. The mean number of individuals/station for this association was 44% and 50% less than the mean for the study area and the OROA, respectively. The mean H '/station was only 4% and 8% less than those for the study area and the OROA, respectively (Table 2). These relatively simple community structures resulted primarily from the homogeneous nature of the substrates, as well as the slower current typical at these stations. Allochthonous organic material typically formed a mat of decomposing litter (mainly leaves) up to 0.5 m deep, effectively deterring many organisms. The presence of *Crangonyx* spp., *Gammarus fasciatus, Caecidotea* spp., *Lirceus* spp. and several odonate taxa indicated relatively unpolluted water. The community structures were dominated by collectors and shredders which constituted 68% of the taxa (Table 1).

CHANNELIZED DITCHES-INTENSE AGRICULTURE ASSOCIATION (CDAA)

These stations (6,7,14,17-20 and 26-30) formed a distinct unit. Although not definable as pollution, habitat alteration can be just as damaging to the biota. Major concerns in this association were drainage of land for agriculture and channelization as a flood control measure. The mean number of taxa/station was only slightly greater than that for the SFLA but was 18% and 36% less than the means for the study area and the OROA, respectively. The mean number of individuals/station was 11%, 41% and 55% less than those of the SFLA, the study area and the OROA, respectively. The mean H '/station was slightly greater than that of the SFLA, and only 1% and 4% less than those of the study area and the OROA, respectively (Table 2). Typical habitat characteristics within this association were dredged channels with a hard-clay bank substrate, high turbidity, a lack of aquatic vegetation and a moderate to fairly swift current. From 50-100% of the watershed was typically involved in agricultural activity. Fifty percent of the taxa and 51% of the individuals collected within this association were Hemiptera and Coleoptera. Very few bivalves, amphipods or isopods were collected, which along with the low numbers of plecopterans, odonates and trichopterans, reflected an obviously disturbed ecological environment (Table 1).

The only obvious seasonal influence was that of rainfall. In a very broad sense, the seasonal patterns exhibited by the aquatic macroinvertebrate communities revealed greater values during the periods of the least rainfall, whereas periods of greater rainfall brought about distinct drops in all parameters measured. Only 35% of the annual precipitation fell between May and October. This was reflected in means of 30 taxa/station and 211 individuals/station and a mean H ' value of 3.592/station. Conversely, from November to April, during which 65% of the annual rainfall occurred, the mean number of taxa/station decreased 50%, the mean number of individuals/station decreased 10%, and the mean H '/station decreased 35%. The lesser values were attributed in large part to water level inereases up to 1.2 m, which resulted in dilution of populations and diminished collecting success.

Our hypothesis that the Sunken Lands may function as a refugium has been supported by this study. *Taphromysis louisianae* previously has been reported only from roadside ditches in Louisiana, although Pennak (1978) stated this opossum shrimp may be widely distributed along the gulf coast. We collected 23 specimens from 4 stations, primarily in the CDPA (Table 1). This population appears to be quite disjunct from the known range of the species. *Baetisca obesa* is also reported as a new record for Arkansas. Its reported range suggested that it should occur in eastern Arkansas (Pescador and Berner, 1981), and our 12 specimens from the OROA and CDAA confirm this (Table 1). Finally, a single specimen of *Corisella inscripta* was collected at station 18 in the CDAA (Table 1). Its U.S. range has previously been reported as extending from Texas and southern Colorado to California and Washington (Hungerford, 1948).

SUMMARY

By every measure, the aquatic macroinvertebrate communities with the most complex structures, and thereby the greatest stability, were found in the OROA. These complex community structures were linked directly to a highly-variable physical environment (one which had not as yet been severely impacted by man's activities).

The SFLA, although reflecting relatively simple community structures, supported several sensitive taxa that indicated a fairly undisturbed association. The simplicity was not attributed to man's activities but rather to the homogeneity of the substrate resulting from the silt load deposited in the near absence of current,which restricted macrohabitat diversity.

Man's alteration of the habitat within the CDAA resulted in the least complex aquatic macroinvertebrate community structures. Their instability was illustrated by the low numbers of taxa, individuals and diversity indices and was a direct result of the restricted physical environment available within the waterways, as well as the activities within the watershed.

Seasonal variations in community structures were primarily related to water level fluctuations, i.e. rainfall. The low-water period was characterized by the greater diversity indices values, while the high-water period inversely produced the lesser values. This inverted relationship was attributed to the dilution of the aquatic macroinvertebrate populations and concomitant adverse collecting conditions.

Our hypothesis that the Sunken Lands may function as a refugium is supported by our finding 3 species of aquatic macroinvertebrates previously unreported for the state; *Taphromysis louisianae, Baetisca obesa* and *Corisella inscripta*.

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AN ON-LINE PROCESS FIBER OPTIC REFRACTOMETER FOR MEASURING EDIBLE OIL HYDROGENATION

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ABSTRACT

The process of edible oil partial hydrogenation has improved steadily over the past decades, but few on-line process instruments exist capable of measuring the extent of hydrogenation. This work describes the design of a prototype, on-line fiber optic refractometer for controlling and monitoring of oils. It uses an established correlation between the degree of hydrogenation of an edible oil and its refractive index (RI).

The refractometer cell uses a bare optical fiber in direct contact with processing oil. Equations are given describing the power transmission characteristics of an optical fiber as a function of its cladding RI. Comparisons between calculated and experimental data are shown using test liquids flowing through the refractometer.

INTRODUCTION

Soybean oil consists of triglyceride molecules. Typically, each molecule's three fatty esters occur in 1 of 3 unconjugated carbon-carbon double bond forms: linolenic, linoleic and oleic. Linolenic, with all 3 double bonds, is the most common. It is also the most easily oxidized. As the oil undergoes catalytic partial hydrogenation, selective double bonds are altered and the oil becomes more stable. Its melting temperature also increases (Table 1). Measuring and controlling these characteristics accurately and consistently is important to the oil processor (Hastert, 1988).

Table 1. Characteristics of fatty acids.

Fatty Ester	Relative Oxidation Rate	Relative Hydrogenation Reactivity	Melting Point
Stearic	1	--	70°C
Oleic	10	1	16°C
Linoleic	100	20	-7°C
Linolenic	150	40	-13°C

Hydrogenation is accomplished by mixing the oil, a small amount of catalyst (nickel powder) and hydrogen gas in a pressurized, heated reactor. Time, pressure and temperature determine how many hydrogen atoms become attached to the esters, altering their characteristics (Hastert, 1981).

The relationship between extent of oil hydrogenation and its refractive index (RI) is well-known. Increasing hydrogenation reduces RI. Measuring RI is the accepted standard method for assessing hydrogenation levels during edible oil processing (Bailey, 1982). For soybean oil, RI ranges from 1.4635 to 1.4564 at 50°C (Riceland Foods, 1989). The method is accurate, using standard refractometers (AOCS, 1973). But it is performed off-line, which interrupts the hydrogenation process for significant periods of time. The process is stopped; a sample extracted, and its RI determined using the refractometer, generally with a heated sample cell. The process is repeatedly nudged foward until the desired hydrogenation is reached. If overshoot occurs, the batch must be used for a recipe requiring more hydrogenation. Increased hydrogenation (saturation) results in a more expensive and less saleable oil.

METHODS AND MATERIALS

The fiber optic refractometer cell, shown in Figure 1, incorporates a single fiber in which a portion of the jacket and cladding have been chemically removed, exposing the silica core. The processing oil circulates around the exposed core, and light passing through the fiber is attenuated according the oil's refractive index.

The numerical aperture (NA) of an optical fiber is defined as NA = sinα (Figure 2). Light entering the fiber within the NA propagates through its length; all other light is lost. Using Snell's law at the fiber end and at the core/cladding interface, NA may be derived as (Snyder & Love, 1983):

$$NA = \sin\alpha = (n_{co}^2 - n_{cL}^2)^{1/2}$$

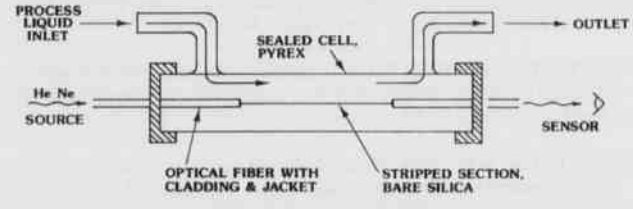

Figure 1. Prototype fiber optic refractometer cell.

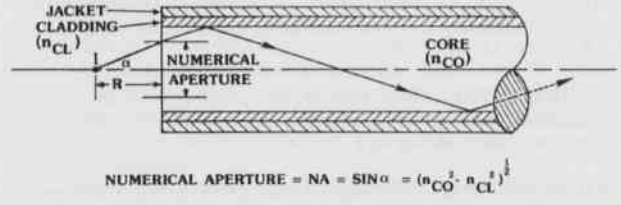

Figure 2. Light transmission in an optical fiber.

where n_{co} and n_{cL} are the core and cladding RI's, respectively ($n_{co} > n_{cL}$). Considering a point source, with intensity, I, at a distance, R, from the fiber end, the area, A, of the NA is approximately:

$$A = \pi(R\sin\alpha)^2 = \pi R^2(n_{co}^2 - n_{cL}^2)$$

The power, P_t, transmitted through the NA is:

$$P_t = I\Omega = \frac{IA}{R^2} = \pi I(n_{co}^2 - n_{cL}^2)$$

where Ω is the solid angle subtended by the NA.

In the fiber optic refractometer, the processing oil becomes the fiber cladding, affecting the fiber's light transmission characteristics (Paul & Kychakoff, 1987; DeGrandpre & Burgess, 1988; Harmer, 1983). Figure 3 shows calculated values of normalized P_t vs n_{cL} for n_{co} = 1.4590. The relationship is approximately linear over the range of interest.

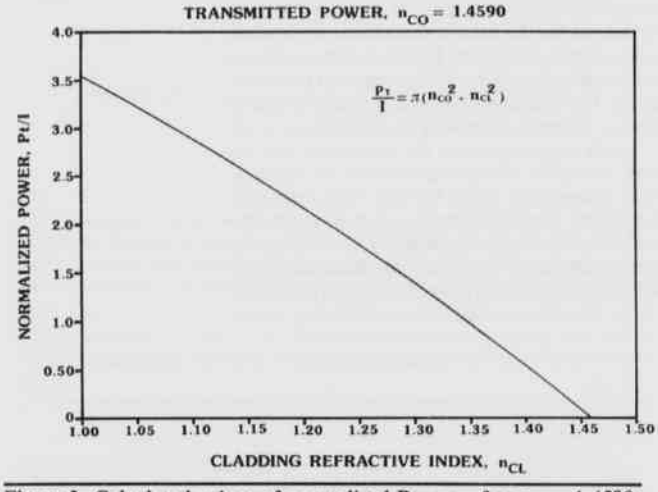

Figure 3. Calculated values of normalized P_t vs n_{cL} for n_{co} = 1.4590.

P_t vs RI was measured using a helium-neon laser as the source and an EG&G radiometer as the sensor. The refractometer test liquid, held at 30 °C, was a solution of corn syrup (RI = 1.4756) and distilled water (RI = 1.3319). The solution RI was varied by dilution. The test liquid was maintained at 30 °C to remove temperature effects. The test liquid RI was determined with an Abbe' refractometer. A least squares fit on the data predicted a core RI of 1.4581. Figure 4 shows the correlation of measured and calculated curves.

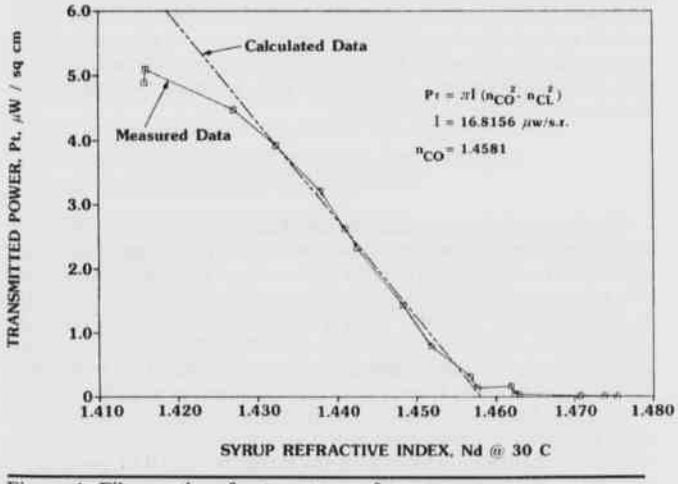

Figure 4. Fiber optic refractometer performance.

DISCUSSION

The response of the fiber optic refractometer cell agrees closely with calculations. The extrapolated least squares fit curve intersected the abscissa at RI = 1.4581. This was unexpected because references had stated the RI of silica at 1.4590 (Corning Glass, 1965). However, data from the specific optical fiber manufacturer shows the RI to be 1.45847 (Fiberguide Ind., 1990). The helium-neon light (wavelength = 632.8 nm) may account for error since the standard light for measuring RI is the D-line of sodium (wavelength = 589.3 nm). The Abbe' refractometer is calibrated to this standard. This difference in wavelengths and unequal dispersions of the core and liquid would introduce error. Deviation from the calculated curve at low RI is due to the fiber's own NA. Its cladding RI is approximately 1.4100 (Fiberguide Ind., 1990). As the test liquid RI decreases below that of the cladding, the fiber's own NA limits P_t.

The effect of temperature on oil RI is significant, and a refractometer cell design must take into account this temperature dependence. Soybean oil, for example, has an RI temperature coefficient of −.000385/°C (AOCS, 1973). Thus to achieve the desired sensitivity, the uncertainty in temperature must not exceed 0.1 °C. Accuracy will be achieved either by closely controlling the cell/liquid temperature or by measuring the cell/liquid temperature and compensating the reading.

The present refractometer cell design exhibits optical noise as the solution RI approaches coincidence to the core RI. Ideally, power throughput is zero at coincidence: the data does not indicate this null value. Observing the refractometer cell under test conditions shows that the light being lost in the optical fiber becomes trapped inside the cell, possibly reflecting light back into the fiber. An improved cell with light absorbing walls and fiber shielding, except on the exposed core section, is being constructed for further testing.

The final design must also take into account the presence of nickel catalyst during hydrogenation processing. The catalyst concentration is approximately one part in 5,600. Its absorbance characteristics, though small, may have an effect on the fiber's power transmission.

CONCLUSIONS

The concept of optical power transmission vs refractive index for the fiber optic refractometer holds true as calculated. The expected relationship shows that such a device could be used to perform real time measurements on edible oils and generate a signal proportional to refractive index. This signal could be used in a process control loop to automatically control the partial hydrogenation of such oils.

Moreover, this instrument holds promise of performing refractive index measurements on liquids compatible with optical fibers and whose RI's are close to that of a fiber.

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UNIVERSITY BASED MULTIDISCIPLINARY ORGANIZATIONS - PROMISES AND CHALLENGES

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ABSTRACT

The Diagnostic Instrumentation and Analysis Laboratory (DIAL) at Mississippi State University is a multidisciplinary research organization engaged in developing and applying advanced computer-controlled, optical and laser-based diagnostic instrumentation systems for the characterization of high temperature gas streams. Part of the mission of DIAL is the on-site application of the diagnostic systems to large-scale facilities. The laboratory has approximately 40 professional and support personnel. Twelve faculty members are associated with the laboratory and, because of the multidisciplinary nature of the research program, their disciplines cross college as well as departmental boundaries. This provides for unique graduate research opportunities. Moreover, the laboratory employees 12 full-time research scientists and engineers in addition to a number of technicians and graduate students. The overall program of the laboratory and the rationale for such mission-oriented organizations are presented. In addition, it is pointed out that an organization of this type presents particular administrative problems in universities. While the path from instructor to university president is well laid out in the tenure track system, the administrative path in which the cross-disciplinary researchers find themselves is often unexplored by them or university administrators. Though there are clearly numerous advantages to this kind of organization, there are also disadvantages. Most of these advantages and disadvantages apply to many cross-disciplinary research groups to varying degrees, and these are also discussed in a general way. Recommendations for interfacing cross-disciplinary research groups are also given.

INTRODUCTION

It is well know that American industry's technological edge is continually eroding and the competitive position of U.S. industries will only worsen with time unless a concerted effort is made to improve this situation. Even though there is an ever increasing body of basic knowledge (upwards of a million scientific articles are published each year) with continued and rapid advancement in various technological areas, the implementation and transformation of this knowledge and technology by U.S. companies into industrial improvements is not, at present, very effective.

This problem is due partly to the short-term profit motive approach and to the lack of reward or incentive at any level in taking technical or financial risks. In addition, there are no effective federal or state programs to enable industry to take advantage of the extensive research and development work being carried out by universities and federal laboratories. Looking at the future Japanese challenge and at a unified Europe, the question is whether the U.S. will be a player or an observer in the future technology game. Fortunately, there are strong indications that there is a growing desire on industry's part for government to facilitate university/industry technology transfer solutions (Adam, 1990).

American industry needs a program today for increased productivity and competitiveness like that provided the American farmer by the Morrill Act of 1862. This act, which established the land-grant colleges, brought the many disciplines of the academic community to bear on agricultural problems. The success of this program is unarguable. Today the U.S. is the world leader in agriculture. It is clearly not necessary or feasible to establish new universities to aid industry. Rather, a serious and expanded effort to bring together a variety of disciplines to focus on technological problems and to transfer in a direct way that technology to industry will provide the advantage required to compete globally.

In principle, technology transfer is best accomplished in the context of a university setting with an interdisciplinary, mission-oriented, research group, where the talents and expertise of a number of disciplines can be brought to bear on a particular problem or class of problems. This clearly provides several advantages that are discussed in this paper. Various rationales other than technology transfer have lead many American universities to form cross-disciplinary research groups (CDRG's). Often, however, these groups are composed of only a few professors and possibly some support staff. Many technological problems require the expertise of a large number of individuals from a multitude of disciplines. These disciplines can easily cross college as well as departmental boundaries. The effective pursuit of the research objective requires the formation of these large CDRG's with the appropriate support personnel and equipment. Unfortunately, the goals of such a group are not always consistent with the historical expectations of a university in regard to teaching and research, the latter as judged by refereed publications. These characteristics present special problems and challenes as discussed later in this paper. As we point out, an appropriate organizational structure must be formed to allow these programs to flourish. Unless this is done, universities will not provide the focused research necessary to gain a competitive edge in the global economy for U.S. industry.

ORGANIZATION

The Diagnostic Instrumentation and Analysis Laboratory (DIAL) at Mississippi State University has a new program specifically designed to provide for technology transfer in the area of advanced diagnostics. The major divisions of the laboratory are illustrated in Fig. 1. DIAL is an example of a CDRG being a large, multidisciplinary research organization engaged in developing instrumentation systems for the characterization of high temperature gas streams (Bauman, *et al.* 1989; Cook, 365 *et al.* 1985; Hester, *et al.* 1989; Lindner, *et al.* 1989; Wilson, *et al.* 1988; Yueh, *et al.* 1988). Depending on the physical parameter to be measured, the most applicable diagnostic technique is chosen and the specific hardware is assembled and integrated by DIAL personnel. The measurement system is also interfaced with a computer and software developed for control and data acquisition. Some of the diagnostic systems which are developed, or are being developed, are listed in Table 1. The modeling group is responsible for developing models needed to interpret the optical spectroscopic measurements, and models to describe specific large-scale devices. Prototype diagnostic techniques and instruments are tested on a computer-controlled combustion test stand used to simulate the combustion and thermal parameters present at various locations in a fossil-fueled combustion system. Its versatility allows it to be used to simulate any type of combustion condition and

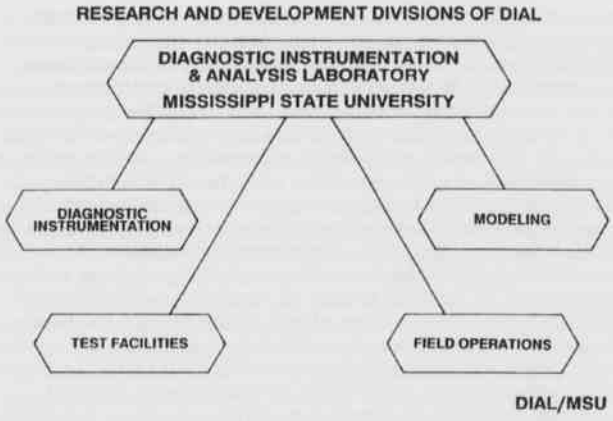

Figure 1. Research and Development Divisions of the Diagnostic Instrumentation and Analysis Laboratory at Mississippi State University.

Table 1. Diagnostic Systems for Characterization of High Temperature Flows

Sodium Line Reversal System (Average Gas Temperature)
Potassium Emission Absorption System (Time Resolved Temperature, K-Atom Density, Electron Density)
Multi-Color Pyrometer System (Wall Temperature and Emissivity)
Two-Color Laser Transmissometer System (Average Particle Size and Particle Number Density)
Laser Doppler Velocimeter System (Local Velocity, Velocity Profile and Turbulence Level)
Gas Analysis System (Gas Composition, e.g., CO, NO, etc.)
Intrusive Multi-Probe System (Optical Temperature Probes -- Wall and Gas Temperature)
Coherent Anti-Stokes Raman Spectroscopy System (Local Gas Temperature and Species Concentration, Temperature and Concentration Profiles)
Particle Size Distribution System (Particle Size Distribution)
Multi-Purpose Imaging System (K-Atom Density, Pressure Profile)
Faraday Rotation System (Electron Density)
Cross Correlation System (Flow Velocity)
Differential Absorption Laser Spectroscopy System (Species Concentration, SO2, NO2, NO, H2O, OH)
Laser Optogalvanic Spectroscopy System (Average Gas Temperature, Qualitative Species Indentification)
Fourier Transform Infrared Gas Analysis System (General Purpose, Rapid, Gas Analysis System)

effluent gas stream. Part of DIAL's program is the application of the diagnostic systems to large-scale facilities. The laboratory staff has, therefore, considerable expertise and experience in using these instruments in the field. DIAL's field team periodically employs the instrumentation systems to measure important combustion parameters in the harsh gas stream environment of magnethohydrodynamic (MHD) test facilities at a number of Department of Energy (DOE) locations around the country. To provide on-site measurements, a large trailer is used to house diagnostic equipment for transportation to, and for use at, a particular facility. Capabilities are provided for use of optical tables for certain laster-based systems. This mobile instrument laboratory has on-board computers for both data acquisition and control of the diagnostic equipment and for on-line data analysis and graphical display of the data in the field.

The development of DIAL's instrumentation systems has not been the work of a single investigator, but a team effort involving engineers from 4 engineering departments, viz., Electrical, Mechanical, Aerospace, Chemical, and scientists from an equal number of science departments, viz., Physics, Chemistry, Computer Science, and Mathematics. The synergistic effect of all team members bringing their expertise to bear on problems has resulted in state-of-the-art instruments that are integrated into a central data acquisition system and are suitable for operation in harsh, real world environments thus extending many diagnostic techniques from the laboratory to the field.

DIAL has approximately 40 professional and support personnel. Twelve faculty members are associated with the laboratory and because of the multidisciplinary nature of the research program, their disciplines cross departmental as well as college boundaries. Moreover, the laboratory employs 12 full-time research scientists and engineers in addition to a number of technicians and graduate students. The breakdown of DIAL's personnel is shown in Fig. 2.

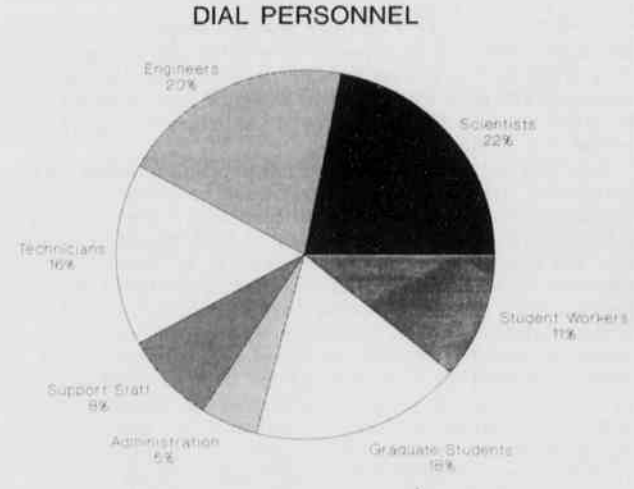

Figure 2. Breakdown of DIAL personnel by category

DIAL PROGRAMS

To provide added insight into a CDRG, we will discuss some of the specific programs of the laboratory. This is necessary to properly understand the advantages and disadvantages of such an organization discussed later, as well as our recommendations for properly interfacing a CDRG with a university. Of course, no single CDRG can possibly include all of the listed advantages or disadvantages. DIAL, however, is a large, diverse CDRG and the authors are experienced with the evolution of this organization over the past decade and hence have an appreciation for the benefits and the problems which can arise.

The overall objectives (see Fig. 3) and approach of the laboratory area as follows:

MISSION - *DIAL's comprehensive mission is to develop and apply advanced optical diagnostic methods to large-scale combustion systems and various manufacturing processes.* Typical industrial applications are found in the chemical, fertilizer, forest products, and oil industries.

GOAL - *DIAL's goal is to improve the effectiveness and competitiveness of U.S. industry through technology transfer of advanced optical diagnostic techniques and thereby impact the understanding, efficiency and environmental safety of industrial processes.* Improving the quality of life and environmental safety through lower emis-

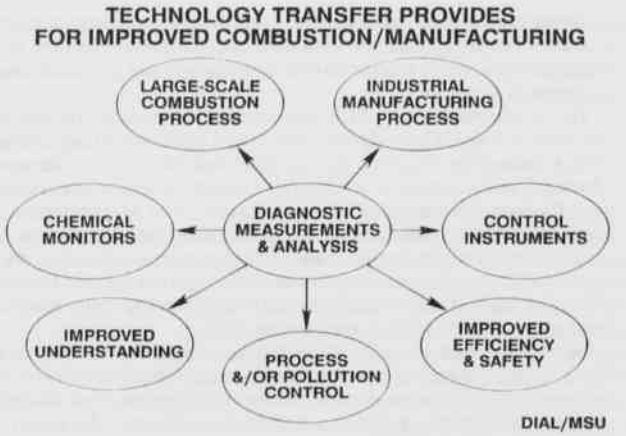

Figure 3. DIAL objectives.

sions of hazardous and toxic waste by developing more efficient chemical reaction processes is particularly important.

APPROACH - *DIAL's approach involes a unique interdisciplinary laboratory employing the expertise of scientists and engineers with a systems approach to address the many and varied diagnostic problems associated with large-scale industrial processes.* Such problems are not effectively solved with small groups of researchers but require the expertise of a number of disciplines.

Since diagnostic techniques applicable to practical devices are often particularly extensive, it makes considerable economic sense to have a laboratory with state-of-the-art instrumentation prepared to carry out field measurements and to provide data analysis, measurement evaluation and interpretation leading ultimately to an improved process. Moreover, measurements with advanced optical and laser-based techniques prove the applicability of the diagnostic technique, provide data to test combustion models, manufacturing process models, and the information needed to ultimately provide modern industrial sensors. The research effort of this laboratory can lead to increased understanding of the process, reliable models, control strategies, diagnostic and control instrumentation, technology refinements, and hence can have a significant impact on modern energy production processes and the effectiveness and competitiveness of many manufacturing industries. To address the specific problems and needs associated with large-scale industrial processes and to directly affect the engineering science base of such systems, various programs have been formulated by DIAL for technology transfer, diagnostic instrumentation development, analytical model development and validation, and for assistance in defining diagnostic research requirements.

ADVANTAGES

It has become apparent in recent years that the most effective way to approach some of the more challenging research problems is to bring to bear the expertise of 2 or more disciplines. The synergistic effect of the CDRG can lead to not only an efficient solution of the problem under investigation but can sometimes lead to fundamental discoveries as by-products of this work. The record suggests that it will not be necessary to despair for the future of fundamental discovery if a more applied cast is lent to some areas of university research (Allen, *et al.* 1989). It is apparent that there are strong motivations for the formation of CDRG's. In addition, the ability to support teams that include technicians, machinists, draftspersons, technical editors, etc., makes this type of organization attractive to the individual researchers as it relieves them of some of the tedium associated with the traditional approach.

There are a number of benefits to a problem-oriented, multidisciplinary laboratory, particularly if that laboratory has been able to attract federal and/or industrial support, and if the university involved, though emphasizing research, does not have a large research or funding base. With such a CDRG, modern state-of-the-art laboratory equipment is available for instruction and research to departments that do not have comparable equipment. Also, graduate programs are strengthened by providing assistantships for students, research opportunities for both faculty and students, and expertise to develop and teach new specialized courses associated with the CDRG mission. The undergraduate science and engineering programs are strengthened by providing undergraduates the opportunity to work part-time with the CDRG researchers. In addition, permanent professional staff members are available as adjunct faculty with appropriate departments, and joint appointments of teaching faculty via research appointments with a CDRG make possible the hiring of outstanding faculty. Furthermore, departments can gain research overhead through these joint appointments. Finally, national and international visibility of a CDRG can focus on the university and, in particular, the departments involved.

Another important advantage of a CDRG is that it can provide the opportunity to develop a unique interdisciplinary academic program based on the mission of the particular CDRG. This is best accomplished at the graduate level with graduate courses coming from the traditional departmental listings as well as specialized courses developed and taught by the CDRG personnel. Such interdisciplinary degree programs will be more important in the future. The presence of an academic as well as a research mission is also an important plus when the interfacing of such an organization within the university is considered as discussed later.

Many of the benefits mentioned here are quite generic in nature and apply to most CDRG's. Another contribution of CDRG's whose mission aids local and state industries to improve their effectiveness is that direct economic development can ensue. This, in turn, provides an immediate and visible basis for judging the importance and contributions of university-based research. The usual claims that strong university programs lead to economic development are actually long-term expectations, although research monies, of course, do provide immediate effects on the local economy.

DISADVANTAGES

Previously, we have presented the rationale for a mission-oriented laboratory and have pointed out the importance that they can have on technology transfer and economic development. The concept is receiving attention within the federal government, and both universities and industries are starting to appreciate the importance of such an organization. Although the advantages are many, nonetheless, it must be admitted that there are problems with such a laboratory dealing mostly with perceptions, evaluation standards and administrative conflicts. In this section we discuss, in a general way, typical problems which can arise.

Research with a cross-disciplinary, product-driven focus runs counter to the established structure and protocol of universities (Pipes, 1987). The resistance to the CDRG has its roots in this disruption. This resistance can only be overcome by forceful support of the CDRG's by the university administration. The CDRG is often looked on as an intruder in the traditional academic departmental structure. It is seen by some administrators as a competitor for research dollars, talented people, and limited resources (Kash, *et al.* 1988). The fact that it is, for the most part, mission-oriented flies in the face of the conventional research paradigms and thus, the unfair perception of low quality is often held by those not associated with the CDRG. This quality perception can be a very difficult obstacle to overcome. It affects the professional relationships within departments toward those who hold joint appointments in CDRG's and can be disastrous when promotion and tenure decisions are made. This is especially true if those decisions are made external to the CDRG.

Another difficulty is in attracting quality faculty willing to work on applied problem-oriented projects in a traditional university setting. Faculty often would prefer to carry out a more basic line of research. When we refer to faculty here, we mean teaching faculty with a joint appointment to a CDRG. An additional problem deals with the so-called

"unfaculty" (Teich, 1979). The unfaculty are members of a CDRG who do not hold an academic department appointment. These unfaculty often possess credentials equivalent to faculty members. Without the faculty appointment, these researchers are often left out of university decisions and given the feeling of being an unwanted step-child. Attempts to solve this problem by giving equivalent rank to full-time researchers is not particularly successful, because this rank usually does not carry conventional benefits given faculty members such as tenure or sabbatical leave. Also, if the CDRG is located in one college, then faculty from a second college who hold academic appointments in their departments are given university input through their departments, but have no input in decision making bodies of the CDRG's college.

Universities, in general, have little experience with this type of organization and are often unable to properly evaluate the performance of faculty members associated with such groups. University promotion standards are usually not directly applicable to faculty members in a mission-oriented program. In addition, "turf battles" can readily arise with regard to the question of who gets the appropriate credit - which department, which college, which dean, which member of the laboratory team, etc.

A number of university administrators would argue that an individual's performance in teaching, research and service is the basis for promotion with perhaps a stated emphasis, whether real or not, on teaching. On the other hand, the attitude on many other campuses is that teaching is not particularly important but rather research is what determines a faculty member's salary and promotion. The reason for this is obvious. A productive researcher who attracts external funding improves the reputation of the department and university while the overhead from such funds enriches the entire university, as well as the local and state economy.

Considering these circumstances, would not the faculty associated with the type of laboratory discussed here be in a good position with regard to promotion and tenure? The answer is — not necessarily. How is research to be judged? Usually, the bottom line is the number of refereed publications and the number of books. On the other hand, a mission-oriented applied group will publish mostly reports, technical summaries, and papers for conferences and proceedings. These do not carry the same weight, and often times there are no refereed publications suitable to the research being performed. One extreme of this situation would be a university group simply carrying out a proprietary research project for some industrial company. Few, if any, publications would result from this situation. However, this is easier for a university to deal with, having made the commitment to perform such a service.

In addition, work done by a CDRG tends to be associated with the group and not with an individual. Publications coming from a CDRG will often have multiple authors. This is as it should be since each individual makes significant contributions but the product is the result of everyone's efforts. The danger with this is that universities tend to place greater emphasis on individual authorship, and on individual work, rather than on group efforts. This can be detrimental to a young faculty member who is trying to establish his research record in order to obtain tenure, and therefore a deterrent for young faculty members to participate in CDRG's. A further discussion of this and other dilemmas may be found elsewhere (Saxberg, *et al.* 1981).

We have noted that refereed papers dealing with more basic studies are harder to come by in a mission-oriented laboratory. This may be illustrated by considering an example in the area of diagnostic development. A typical research project might be to develop and apply an instrument to measure a particular physical property on a large-scale device. The development procedure would involve selection of the appropriate optical technique, selection and acquisition of the required equipment, integration of these components, followed by bench-top experiments to evaluate the method. If this proves successful, then computer interfacing would follow for system control and data collection. This could take upwards of 2 years for a faculty member heading this development and working at 50% time for the laboratory. Application of the system to a practical gas stream, the original goal, could provide the realization that some basic research work is required to properly implement the technique to a large-scale device. Assuming this work is successful, the research and development project could yield a refereed publication, a number of technical reports, and most likely a significant impact on some applied industrial problem. The question is whether an average of one refereed publication over 3 or 4 years is sufficient to warrant promotion and/or tenure. This, however, is often the nature of applied studies. Also, because of priorities, time to pursue avenues of basic research which become apparent cannot always be provided without directly impacting the applied development work. The same effort using the equipment in a laboratory setting could well have yielded two or three publications.

These problems are particularly acute for junior faculty members. One way out of this dilemma is to allow only senior faculty to work with such an organization. This, however, is clearly not a satisfactory solution, and moreover even senior faculty are not immune to publication pressures. From the above discussion it is apparent that the accomplishment of the mission, i.e., successful development of the instrument, must be included in any fair evaluation of the faculty member's performance.

CONCLUSIONS AND RECOMMENDATIONS

We have pointed out the advantages of CDRG's and how they fulfill a necessary role. The interdisciplinary aspect allows for new ideas to be generated by providing ready interaction between different disciplines. The focused approach serves to maximize the research effort and problem solving capabilities of the group. In principle, the advantages far outweight the disadvantages; however, for CDRG's to be successful, a better way to interface these organizations with the university structure must be found. It should be emphasized that these interfacing problems apply to most CDRG's to varying degrees. Here we give a few recommendations and alternative interfacing suggestions for CDRG's.

Clearly, an organization must operate under a set of guidelines relative to promotion, salary, etc. These guidelines need to be set in concert with the university administration, and need to be independent of whether you are faculty or unfaculty. The difficulty arises in trying to employ existing guidelines to evaluate a CDRG member as pointed out previously. If the university organization is such that individual departments effectively set the standards and evaluate its members directly for promotion and/or tenure, and the role of the college or dean is minimal, then the obvious way to interface a CDRG is to raise it to the level of department having all the rights and privileges of any other department in the university. This interfacing mode is particularly easy if a CDRG has its own interdisciplinary graduate program offering an MS or a PhD level degree. Under these conditions, the difference between the CDRG and traditional academic departments is significantly diminished. Unfortunately, all degree programs are usually through traditional departments and the CDRG has no specific academic role.

In most universities, the departments are subject to certain restrictive guidelines imposed by a college; in fact, their decisions are often reviewed by a college committee which reflects the traditional standards imposed on faculty in the areas of teaching, research, and service. Under these circumstances, the above interfacing solution will not work smoothly and perhaps not at all. Clearly, this situation is further complicated by the lack of a traditional academic role. Unless a CDRG is able to adopt rules and regulations for promotion that reflect its mission it cannot readily prosper. Moreover, the rules must apply to both faculty and unfaculty. As far as joint-appointments with teaching faculty from other departments are concerned, it must be understood that their research will be judged by the CDRG. In the setting of faculty salaries and the sharing of overhead, explicit communication between the CDRG and the appropriate department must be part of the interface. The CDRG mission and the difference in its mission must be recognized by all.

Probably the easiest way to interface such an organization effectively in most university frameworks is to put the group under a separate vice president who appreciates the CDRG concept and who will be a forceful leader and spokesperson for the group. The evaluation guidelines for promotion, etc., can then be independent of any particular college or department. Joint appointments are possible only if the department understands that the CDRG will judge the research of the teaching faculty member. Under these circumstances there are still ample reasons, as discussed previously, for a department to cooperate

with a CDRG and participate in its program.

Furthermore, it must be noted that if a university accepts the benefits of a CDRG, then it must also accept the responsibility to support it like any other department of the university. It therefore deserves and requires financial support, and moreover, a reasonable number of permanent positions (not necessarily tenure-track positions) need to be associated with the organization.

Finally, we feel that more such organizations will be instituted — their time has come. If universities cannot find a way to effectively and satisfactorily interface these within the university structure then they will be interfaced elsewhere, and this would be a serious loss to the university community. Clearly, many of the problems addressed in this article would not exist if only unfaculty were involved; however, without significant faculty participation the organization would no longer be a true university based multidisciplinary organization.

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COMPARISON OF THE MOLECULAR STRUCTURES OF MONOVALENT CATION SALTS OF N,N-DIMETHYLDITHIOCARBAMATE. NOVEL SYNTHESIS AND CRYSTAL STRUCTURE OF $(P\emptyset_4)(S_2CN(CH_3)_2)2H_2O$

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ABSTRACT

Crystals of the tetraphenylphosphonium N,N-dimethyldithiocarbamate dihydrate ($C_{27}H_{30}NO_2PS_2$; F.W. = 495.6) are monoclinic; $P2_1/n$; a = 13.349(6), b = 20,968(6), c = 9.800(4) Å, β = 109.01(3) °; Z = 4; V = 2593.4(16) Å^3; D_x = 1.269 gcm^{-3}. Data were collected at ambient temperature using MoK_α radiation (λ = 0.71069 Å). F(000) = 1048, linear absorption coefficient, μ = 2.80 cm^{-1}. The structure was solved by direct methods and subsequently refined by full matrix least squares techniques. Final R value = 0.064 for 1610 reflections and 298 varied parameters. Due to the nature of the cation, interactions between the tetraphenylphosphonium group and the sulfur atoms of the anion are absent, unlike previous dimethyldithiocarbamate structures (Na^+, Cs^+, Tl^+). Intermolecular interactions between the waters of hydration and the anion are present.

INTRODUCTION

Attempts to prepare the tetraphenylphosphonium ($P\emptyset_4^+$) salt of $Ni(CS_3)_2^{2-}$ (Fackler and Coucouvanis, 1966) led to the isolation of low yields of $(P\emptyset_4)S_2CN(CH_3)_2$ as a reaction by-product. The dithiocarbamate was characterized by X-ray diffraction techniques. This report describes a novel synthesis and structural comparisons to monovalent cation salts of dimethyldithiocarbamate.

MATERIALS AND METHODS

Crystals of tetraphenylphosphonium dimethyldithiocarbamate, I, were obtained by the slow evaporation of the filtrate from the reaction of ethanolic nickel acetate, a dimethylformamide solution of KOH and CS_2, and aqueous $P\emptyset_4Cl$ (Fackler and Coucouvanis, 1966). The pale yellow crystal was cleaved to give 0.3 x 0.3 x 0.4 mm dimensions. Intensity data were collected on a Syntex P3 automated diffractometer. Unit cell dimensions were determined by least squares refinement of the best angular positions for 15 independent reflections ($2\Theta > 15°$) during normal alignment procedures. Data (3411 points) were collected using a variable scan rate, Θ - 2Θ scan mode and a scan width of 1.2° below $K_\alpha 1$ and 1.2° above $K_\alpha 2$ (h, −14 to +13; k, 0 to +8; l, 0 to +10). Maximum 2Θ value was 45.0°. Backgrounds were measured at each side of the scan for a combined time equal to the total scan time. Corrections were applied for Lorentz, polarization and background effects. No absorption correction was applied. The intensities of three standard reflections (remeasured after every 97 reflections) showed crystal stability. Data reduction ($I < 3.0\ \sigma(I)$) gave 1610 reflections used in the solution and refinement of the structure.

The structure was solved by direct methods for positions of nonhydrogen atoms. Least squares refinement using the X-Ray System program (1980 version) converged with anisotropic thermal parameters. A difference Fourier synthesis allowed location of all hydrogen positions and these were included in the final refinement with isotropic thermal parameters (U_{ii} = 3.97) but all hydrogen parameters were held invariant. Maximum least squares shift to error ratio = 0.4. $\Delta\rho_{max}$ = 0.34 and $\Delta\rho_{min}$ = −0.30 e Å^{-3} on the final difference map. The final cycle of refinement - function minimized ($(|F_o| - |F_c|)^2$, led to final agreement factor, R = 6.4 %, R = $(\Sigma||F_o| - |F_c||/\Sigma|F_o|) \times 100$. A weight equal to $1/\sigma F$ was introduced in the final cycles of refinement: R_w = 8.1 %. S = 0.30, with 298 parameters refined.

Scattering factors were taken from the tables of Cromer and Mann (1968). Anomalous dispersion factors, f′ and f′′ were applied for P and S (Ibers and Hamilton, 1974).

RESULTS

Crystal data are given in Table 1. The structure of $(P\emptyset_4)S_2CN(CH_3)_2$ $2H_2O$, I, is seen in Fig. 1. Atomic positional and thermal parameters are given in Table 2. Selected bond distances and angles can be seen in Table 3.

Table 1. Crystal Data for $(P\emptyset_4)S_2CN(CH_3)_2$-$2H_2O$

Formula	$C_{27}H_{30}NO_2PS_2$
MWT	495.6
Space group	monoclinic $P2_1/n$
a	13.349(6)Å
b	20.968(6)Å
c	9.800(4)Å
ß	109.01(3)°
V	2593.4(16)Å^3
F(000)	1048
μMoK	2.80 cm^{-1}
MoK	0.71069Å
D_{calc}	1.269 gcm^{-3}
Z	4
Observed reflections	1610
R/R_w	6.4/8.1%

Comparison of the Molecular Structures of Monovalent Cation Salts of N,N-Dimethyldithiocarbamate

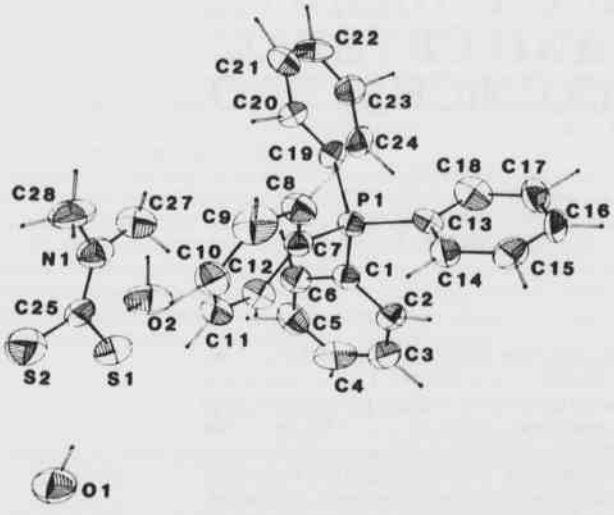

Figure 1. The assymetric unit of $(P\emptyset)_4$ $(S_2CN(CH_3)_2)$-$2H_2O$. Thermal ellipsoids drawn at 50% probability level.

Table 2. Positional Paramaters of Nonhydrogen Atoms for $(\emptyset_4P)$ (dimethyldithiocarbamate) $(H_2O)_2$

ATOM	X(SIG(X))	Y(SIG(Y))	Z(SIG(Z))	Ueq*10
P1	0.6719(2)	0.0386(1)	0.2830(2)	33
S1	0.7375(2)	0.2377(1)	-0.1244(3)	60
S2	0.5842(3)	0.3441(2)	-0.1442(3)	79
O1	0.1785(6)	0.2336(4)	0.0249(7)	81
O2	0.9821(5)	0.1815(4)	0.0147(8)	86
N1	0.6964(6)	0.2892(4)	0.0981(9)	58
C1	0.7363(6)	0.0121(4)	0.1609(8)	35
C2	0.7087(6)	-0.0456(4)	0.0845(9)	41
C3	0.7593(8)	-0.0643(5)	-0.0129(10)	54
C4	0.8332(7)	-0.0250(6)	-0.0386(10)	64
C5	0.8602(8)	0.0311(5)	0.0353(10)	59
C6	0.8151(7)	0.0510(5)	0.1340(9)	44
C7	0.5851(7)	0.1041(4)	0.2056(8)	38
C8	0.5184(7)	0.1271(5)	0.2766(9)	50
C9	0.4512(8)	0.1766(5)	0.2159(12)	65
C10	0.4464(8)	0.2028(5)	0.0831(11)	51
C11	0.5125(8)	0.1784(5)	0.0158(10)	48
C12	0.5810(6)	0.1296(5)	0.0733(9)	43
C13	0.5934(6)	-0.0245(4)	0.3183(8)	37
C14	0.4848(7)	-0.0261(5)	0.2467(9)	43
C15	0.4263(8)	-0.0781(6)	0.2679(10)	57
C16	0.4749(9)	-0.1287(5)	0.3549(11)	64
C17	0.5806(8)	-0.1261(5)	0.4274(10)	58
C18	0.6407(7)	-0.0743(5)	0.4101(10)	59
C19	0.7737(6)	0.0613(4)	0.4481(9)	35
C20	0.7645(7)	0.1181(4)	0.5174(9)	44
C21	0.8406(8)	0.1318(5)	0.6487(10)	51
C22	0.9229(7)	0.0887(6)	0.7083(9)	51
C23	0.9323(8)	0.0334(5)	0.6375(11)	53
C24	0.8563(7)	0.0199(5)	0.5055(10)	47
C25	0.6748(8)	0.2904(5)	-0.0472(10)	50
C27	0.7761(8)	0.2463(5)	0.1910(11)	65
C28	0.6449(9)	0.3286(6)	0.1735(11)	94

*Ueq = 1/3 the time of the diagonalized matrix

Table 3. Bond Angles (°) and Distances (Å) for $(\emptyset_4P)$ (Dimethyldithiocarbamate) $(H_2O)_2$

P1 - C1	1.775(10)	C1 - P1 - C7	109.9(4)
P1 - C7	1.798(8)	C1 - P1 - C13	110.0(4)
P1 - C13	1.790(10)	C1 - P1 - C19	107.3(4)
P1 - C19	1.805(8)	C7 - P1 - C13	108.0(4)
C25 - S1	1.704(11)	C7 - P1 - C19	111.7(4)
C25 - S2	1.700(10)	C13 - P1 - C19	109.8(4)
C25 - N1	1.36(1)	S1 - C25 - S2	123.0(6)
N1 - C27	1.46(1)	S1 - C25 - N1	119.1(7)
N1 - C28	1.42(2)	S2 - C25 - N1	117.9(8)
C1 - C2	1.41(1)	C25 - N1 - C27	121.8(9)

Table 3 (cont.)

C2 - C3	1.39(2)	C25 - N1 - C28	124.0(8)
C3 - C4	1.37(2)	C27 - N1 - C28	114.2(8)
C4 - C5	1.36(2)	P1 - C1 - C2	121.8(7)
C5 - C6	1.36(2)	P1 - C1 - C6	119.8(7)
C6 - C1	1.42(1)	C2 - C1 - C6	118.4(9)
C7 - C8	1.38(1)	C1 - C2 - C3	120.3(9)
C8 - C9	1.37(1)	C2 - C3 - C4	119.7(9)
C9 - C10	1.40(2)	C3 - C4 - C5	120.1(10)
C10 - C11	1.36(2)	C4 - C5 - C6	122.6(10)
C11 - C12	1.36(1)	C5 - C6 - C1	118.8(8)
C12 - C7	1.39(1)	P1 - C7 - C8	119.1(7)
C13 - C14	1.39(1)	P1 - C7 - C12	120.9(7)
C14 - C15	1.40(2)	C7 - C8 - C9	118.8(9)
C15 - C16	1.38(1)	C8 - C9 - C10	121.8(11)
C16 - C17	1.36(1)	C9 - C10 - C11	117.6(9)
C17 - C18	1.39(2)	C10 - C11 - C12	122.3(9)
C18 - C13	1.39(1)	C11 - C12 - C7	119.5(9)
C19 - C20	1.40(1)	C12 - C7 - C8	119.9(8)
C20 - C21	1.38(1)	P1 - C13 - C14	120.0(6)
C21 - C22	1.39(1)	P1 - C13 - C18	120.6(6)
C22 - C23	1.38(2)	C13 - C14 - C15	119.0(8)
C23 - C24	1.39(1)	C14 - C15 - C16	121.2(9)
C24 - C19	1.37(1)	C15 - C16 - C17	119.4(10)
		C16 - C17 - C18	120.5(9)
		C17 - C18 - C13	120.4(8)
		C18 - C13 - C14	119.3(8)
		P1 - C19 - C20	120.1(6)
		P1 - C19 - C24	118.1(7)
		C19 - C20 - C21	118.3(8)
		C20 - C21 - C22	119.6(9)
		C21 - C22 - C23	121.5(8)
		C22 - C23 - C24	118.8(9)
		C23 - C24 - C19	120.0(9)
		C24 - C19 - C20	121.7(7)

DISCUSSION

The synthesis of dithiocarbamates directly from dimethylformamide, DMF, is novel. This can be explained by the base (OH^-) hydrolysis of DMF followed by the nucleophilic attack of the $[N(CH_3)_2^-]$ generated during the reaction, on CS_2. The $(P\emptyset_4)S_2CN(CH_3)_2$ can be prepared directly by the metathesis of $NaS_2CN(CH_3)_2$ and $P\emptyset_4Cl$, and compares well with the product obtained from DMF.

The use of $P\emptyset_4^+$ as counterion prohibits interaction of the cation with the dithiocarbamate anion. In the molecular structures of the Na^+ (Ymen, 1981; Oskarsson and Ymen, 1983), Tl^+ (Jennische and Hesse, 1973), Cs^+ (Wahlberg, 1976) and $NH_2(CH_3)_2^+$ (Wahlberg, 1978) salts, there is direct interaction between cation and anion (see Table 4).

The structure of the Na^+ (Ymen, 1981; Oskarsson and Ymen, 1983) complex indicates that the Na^+ ion is attached to the S atoms of the dithiocarbamate and four O atoms from waters of hydration, forming a distorted octahedral arrangement. Na-S distances are 2.992(1) and 3.015(a) Å. This structure correlates well with the structure of the $NaS_2CN(CH_2)_4$ complex (Albertsson *et al.*, 1980). The Tl^+ reaction yields dimetallic species which are interconnected to one another through long Tl-S interactions, giving rise to layers of these dimers parallel to

the a,b plane (Jennische and Hesse, 1973). The Tl atoms are seven coordinate with the Tl-S distances ranging from 3.0 to 3.7 Å. For Cs^+, a coordination number of 8 is found for the cation in the structure of $CsS_2CN(CH_3)_2$ (Wahlberg, 1976). Cs-S distances range from 3.636(1) to 4.099(a) Å. The $NH_2(CH_3)_2^+$ complex gives a one-dimensional arrangement with the ammonium hydrogens interacting with the sulfurs on the dithiocarbamate. Each dithiocarbamate hydrogen bonds to two $NH_2(CH_3)_2^+$ forming a zig-zag chain (Wahlberg, 1978).

Table 4. Comparisons of Selected Bond Distances (Å) and Angles (°) for Complexes of Dimethyldithiocarbamate

M' =	$(P\emptyset_4)^+$	$(H_2N(CH_3)_2)^+$	Cs^+	Tl^+	$NaS_2CN(CH_2)_4$
S-C-S	123.0	119.7	121.2	121	122.3
S-C-N	118.5	120.2	119.4	120	118.9
C-N-$CH_{3(2)}$	122.9	122.7	121.2	123	124.6
CH_3-N-CH_3	114.2	114.7	117.5	114	-
CH_2-N-CH_2	-	-	-	-	110.8

The Li^+ complex shows an interaction between the waters of hydration and the dithiocarbamate anion (Ymen, 1984). The Li^+ ion is coordinated to four H_2O molecules forming a distorted tetrahedral arrangement. The electron density on the S atom is distributed to the coordinated waters through hydrogen bonds. This is similar to the structure found for $P\emptyset_4(S_2CN(CH_3)_2)$, in which the waters of hydration are hydrogen bonded to the dithiocarbamate anion. Unlike the Li^+ example, the waters do not interact with the $P\emptyset_4^+$ moiety. Thus, the structure reported within is the first example of a monovalent cationic species that does not bind to the dimethyldithiocarbamate ion.

SUPPLEMENTAL MATERIAL

Anisotropic Thermal Parameters, Positional Parameters for the Hydrogen Atoms, and Structure Factor Tables (31 pages) are available from the authors upon request.

ACKNOWLEDGMENT

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A PRELIMINARY STUDY TO DETERMINE THE EFFECT OF MICROWAVES ON GREEN WOOD

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ABSTRACT

A preliminary study was done to determine the moisture content of green wood by treating the wood with microwaves in an oven for various times between 1 and 4 minutes. The temperature of the wood was measured immediately following the radiation with a probe interfaced to a microcomputer and with a mercury-in-glass thermometer. Temperature probes were inserted into the wood samples. Actual moisture content of the wood was determined by weighing the samples before and after drying. Half of the samples exhibited a directly proportional relationship between moisture content and temperature after microwaving. The linear relationship was not generalizable to all green wood samples tested.

INTRODUCTION

The purpose of this experimental study was to determine the relationship between the percentage moisture content of green wood and the temperature produced in the sample after a specific time exposure to microwaves. A survey of literature was conducted but no studies of the same concept were found. Ryley (1969) reported the results of a series of tests using a microwave oven for the rapid determination of the moisture content of soils. Ryley's conclusion was that microwave drying can be used for most soils with comparable accuracy to drying in a conventional oven. However, the results were obtained in a microwave oven in 2 to 15 minutes compared to 16 to 24 hours in the conventional oven.

Fanslow and Saul (1971) reported on the use of microwaves in the drying of field corn. The data showed that a limit existed to the speed of microwave drying. Beyond the limit there was swelling of the corn kernels to lower the market grade.

Hamid (1972) reported successful drying of leather using microwaves.

MATERIALS AND METHODS

Green pine wood was irradiated with microwaves in a 1200 watt oven at a frequency of 2450 MHz. The temperature was measured in this experiment with a conventional mercury-in-glass thermometer and simultaneously with a thermistor probe interfaced to a microcomputer. The thermometers were placed in 0.64 cm diameter by 0.64 cm deep holes bored in the wood samples. The wood samples varied in diameter from 3.5 cm to 6.6 cm by 21 cm long. The microcomputer thermometer probe was calibrated in water to an accuracy of ± 1 °C compared to a mercury-in-glass thermometer over the range of 0 to 100 °C. The microcomputer used a BASIC program which was linearized between calibration points and reported the temperature every three seconds. The microcomputer temperature probe was observed to have a faster response time than the mercury-in-glass thermometer. The samples were weighed on a triple beam balance to the nearest 0.1 g before and after each microwave treatment. The samples were irradiated with microwaves for 1 minute and the temperature was measured by both thermometers as soon as the sample could be removed from the oven. The temperature of the samples was observed to increase for a period of time after the thermometers were placed in the sample, indicating the heating had occurred in the center of the sample and conducted outward to the surface. As soon as a maximum temperature was achieved and recorded on both thermometers, the sample was replaced in the microwave oven and again treated for one minute. The sample was again removed and the maximum temperature measured and recorded. The mass of the sample was again recorded and the sample was allowed to air dry in the laboratory. The samples were then dried in a conventional oven at 65.5 °C for about 44 hours. This oven drying was continued until all samples remained the same mass within 1 g. This dry mass was used to calculate the relative percentage of moisture in the wood samples.

RESULTS

Sixteen samples were tested and all were cut from the green state and were tested at various stages of air drying. The samples varied from 0.8 percent moisture to 53.9%. From observed temperature measurements, the researcher concluded that heating occurred to a considerable depth as the temperature at the depth of 0.64 cm increased for up to several minutes before reaching a maximum indicating the heat was conducted outward from the center of the sample. More reliable data were obtained when the loose bark of the sample was removed and the thermometer placed in small holes bored in the wood. Data from the first 4 samples were unreliable because of the attached bark and were discarded for this study. No simple relationship could be determined between the percentage moisture and the temperature produced because of variation of individual samples.

A least squares fit program was run with the data listed in Table 1. The results found are listed in Table 2. Several unexpected results were noticed during the course of the study. Sample 7 caught fire as evidenced by smoke emission as a result of the microwaving for four minutes. Sample 14 has a negative slope which as believed to be a result of the small sample diameter allowing the change of phase of water as a result of the microwave heating for one minute. Water vapor was observed to be emitted from the sample at the early stages while the sample contained a high moisture content. The same effect was noted for larger diameter samples microwaved for a longer time.

DISCUSSION

A direct proportional relationship was found in half the samples between the percentage moisture content of the green wood and the temperature produced as a result of the microwave treatment as indicated by the high correlations. A general relationship was not found between percentage moisture and temperature of pine wood as shown by the variation in the slopes of various samples. The amount of time the samples were exposed to microwaves was important. Too long an exposure resulted in one sample burning. Small samples with high moisture content and long microwave exposure resulted in a change in phase of the water with no corresponding rise in the temperature of the samples. The amount of time needed to expose the sample to microwaves depends on the mass of the wood. Microwave drying of wood to find the percentage of moisture by weighing reduces the time to make the measurement. No cracking was observed in any of the samples as a result of microwave drying. A study of the drying of hardwoods with microwaves is needed, as well as a study of the relationship between temperature produced by microwaves and percentage of moisture in hardwood samples.

Table 1. Percentage of Moisture in Wood Sample and Temperature Produced by Microwaving.

Diameter(cm)	%Moisture	Temp(T1)	Diameter(cm)	%Moisture	Temp(C2)
5.0	51.9	74	4.1	53.9	85
5.0	22.8	75	4.1	9.8	64
5.0	5.2	67	4.1	5.3	62
5.0	4.8	63	4.1	2.0	59
5.0	1.7	68	4.1	1.5	57.3
5.0	1.4	55			
5.0	1.0	64			

Diameter (cm)	%Moisture	Temp(T1)	Diameter(cm)	%Moisture	Temp(C2)
5.1	11.2	61	5.3	36.9	66
5.1	6.2	59.5	5.3	7.8	60
5.1	2.1	64	5.3	3.2	57.3
5.1	1.2	65.5	5.3	1.2	57.3
			5.3	0.9	57.3
			5.3	0.9	57.3

Diameter(cm)	%Moisture	Temp(C1)	Diameter(cm)	%Moisture	Temp(C1)
4.2	21.9	91	3.5	53.3	44
4.2	11.0	64	3.5	41.1	46
4.2	5.5	58	3.5	36.5	68
4.2	1.9	57.3	3.5	27.5	94
4.2	0.8	47.3	3.5	18.9	88
4.2	0.8	50.7	3.5	5.9	85

T indicates mercury-in-glass thermometer (Celsius) after 1 (T1) min, or 2 (T2) min.

C indicates computer interfaced thermistor (Celsius) after 1 (C1) min, or 2 (C2) min.

Table 2. Least Squares Fit of Data from Table 1

Sample Diameter	Correlation	Slope	Temperature Axis Intercept
5.0	0.495	0.255	63.3
4.1	0.961	0.533	56.7
5.1	0.583	-0.458	64.9
5.3	0.977	0.243	57.2
4.2	0.948	1.839	48.5
3.5	0.676	-1.065	103.4

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THE VEGETATION OF SARATOGA LANDING BLACKLAND PRAIRIE

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ABSTRACT

Saratoga Landing Blackland Prairie is a 75-ha site owned by the U.S. Army Corps of Engineers and managed cooperatively with the Arkansas Natural Heritage Commission to protect its blackland prairie community and rare plant species. The site is a complex of prairies and forests, as interpreted from aerial photos and maps. It was substantially prairie at the time of settlement, and forest cover did not increase greatly until after 1951, apparently due to effective suppression of wildfires after that time. Plot sampling characterizes an individual prairie on the site as being dominated by a herbaceous canopy, but with a substantial woody plant cover (15%-20%). Of the herbaceous vegetation, *Andropogon scoparius* is dominant, with lower seasonal production than the Grand Prairie of eastern Arkansas (147 g/m² vs. 800 g/m²). A recent prescribed burn resulted in a doubling of herbaceous end-of-season biomass, top-killing (but resprouting) of many woody plants, elimination of mulch and increased bare ground.

INTRODUCTION

The blackland prairie community of southwestern Arkansas is related to the similar communities of Texas, Mississippi and Alabama, as described by Collins *et al.* (1975), Jones and Patton (1966), and Rankin (1974). The original distribution, geology and soil, floristics and general vegetation of the Arkansas communities have been described by Foti (1989). The purpose of this study is to describe in detail the vegetation of a prairie and the complex of prairies within which it exists at Saragota Landing Blackland Prairie Natural Area. To the extent possible, the changes in vegetation due to disturbance and protection are also documented, particularly those related to a recent prescribed fire.

SARATOGA LANDING BLACKLAND PRAIRIE NATURAL AREA

The Saragota Landing Blackland Prairie Natural Area is a 75-ha complex of prairies and forest located in Hempstead and Howard counties, Arkansas, in sections 31 and 32, T11SR27W and sections 5 and 6, T12SR27W (Fig. 1). It is owned by the U.S. Army Corps of Engineers (Millwood Lake Project) and cooperatively managed by the Little Rock District, USCE and the Arkansas Natural Heritage Commission to protect and enhance the blackland prairie community and rare species that occur on the site.

The natural area is situated on the east side of Millwood Lake on a substrate of Saratoga Chalk. Located on the Saratoga Cuesta, slopes in prairies range to 30%. The area is a complex of communities including both dry prairie and dry-mesic forest. It was identified through a systematic inventory of potential natural areas of southwestern Arkansas begun by the Arkansas Natural Heritage Commission in 1985, the Coastal Plain Inventory.

The area has been grazed in the past but is recovering from that disturbance. Two primary indicators of disturbance remain: eroded gullies and woody plant invasion of prairies. Even with this evidence of disturbance, the site, when evaluated on the basis of size, diversity, amount of disturbance, and presence of special species, ranks among the best of the blackland prairie areas evaluated during the course of the Coastal Plain Inventory.

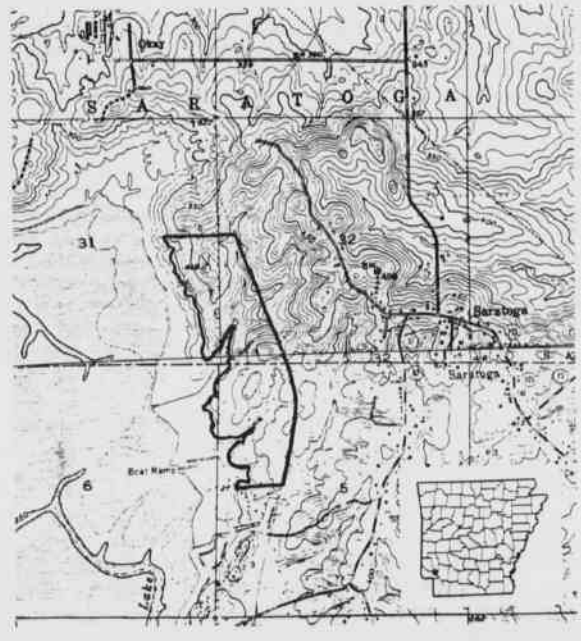

Figure 1. Saratoga Landing Blackland Prairie Natural Area, Howard and Hempstead counties, Arkansas, sections 5 and 6, T12SR27W and sections 31 and 32, T11SR27W.

METHODS

The study of Saratoga Landing Prairie vegetation involved qualitative description of the entire tract and quantitative description of an individual prairie. The distribution and size of prairies and change in these features over time was documented on the whole site and its surroundings through the field notes of the General Land Office (GLO)

Survey, and through aerial photographs taken in 1939, 1951, and 1964 by the Soil Conservation Service, and by the Arkansas Highway Department in 1974 and 1981. These sources were used to show the original character of the site and recent changes caused by grazing, fire and development.

Quantitative description of a single prairie within the complex was done to determine the amount and type of woody vegetation, along with the composition, cover and biomass of the herbaceous vegetation. Permanent sample plots were located along a 300 m transect line through one of the larger prairies on the tract. Ten plots were spaced randomly along the line at intervals of 15 m to 50 m. The center of each plot was marked with metal stakes 1 m long driven to within 15 cm of the end. Although the line was placed within a definable prairie, no attempt was made to avoid small groves of trees and brush. The line also passed under a powerline that crosses the site.

Each stake was used as the center of a 1/50-ha circular plot. An 8 m tape was used as the radius of the circle and provided a direct measurement to any plant near the periphery of the plot. This full 1/50-ha plot was used to estimate the foliage cover of woody plants and to count the total number of individuals of woody plants. The same plot center was used to locate 2 plots for sampling herbaceous vegetation. These plots were 1 m by 0.25 m with their nearest edge centered 2 m north and 2 m south of the main plot center. The areal cover (projection to the ground) by species was estimated within each of these plots, and then the vegetation was clipped, sorted by species or species group, oven-dried 24 hrs. and weighed.

Plots were initially sampled in September, 1987. Resampling occurred in September, 1989, after the prairie was burned under management prescription in March of that year. This second sample allowed preliminary investigation of the effect of fire on community composition and production.

Statistical tests were done using ABSTAT rel. 6.02 (Anderson-Bell, 11479 S. Pine Dr., Parker, CO 80134). The paired-T test was used to test for significance of differences in vegetation parameters between the 2 sample periods.

RESULTS

HISTORICAL VEGETATION OF THE SITE

The Arkansas blackland prairies were typically small, ranging from less than a hectare to a few hundred hectares in size, separated by fringes of trees, shrubs and vines along watercourses (Foti, 1989). Consistent with that pattern, the largest individual prairie on the Saratoga Landing Blackland Prairie Natural Area is about 15 ha. It is uncertain whether this reflects the presettlement condition, since the area has been grazed until acquired by the USCE about 1970. Fire has been excluded for decades according to an adjacent landowner. The past management has probably encouraged the establishment of woody plants, and therefore historical sources were examined to determine the condition originally and in the more recent past.

The GLO notes, made in 1819, before extensive settlement, on the mile that passes north-south through the northern part of the natural area (that is, the south ½ of the line between sections 31 and 32, T11S R27W) call it "broken third-rate prairie land not suited for cultivation." There were trees to mark the quarter section corner, so the area was not treeless. However, the distances to the 2 witness trees were 16 m to a 25 cm diameter white oak and 19 m to a 25 cm diameter black oak; therefore the landscape was open. The two mile lines running east-west a half-mile north of this quarter-corner (that is, between sections 30 and 31 and between sections 29 and 32, ½ mi. north of the natural area) both carry the general comment "mostly prairie". This notation was fairly uncommon in the vicinity, with prairie notations more often taking the form, "2 prairies" or "4 small prairies". Therefore the vicinity of today's natural area was substantially covered with prairie in 1819.

In 1939, when the first aerial photographs of the area were taken, the area was still primarily open prairie, with scattered trees over much of the area, and dense forest in parts, primarily along streams. The 1951 aerial photo of the area shows much the same pattern; however, the 1964 photo shows far more forest land than previously (Fig. 2). A major change in land-management apparently occurred during this interval, probably improved control of wildfires. However, changes in grazing patterns could have played a role. Later aerial photographs indicate that the encroachment of woody plants on the prairie has continued, but at a slower rate.

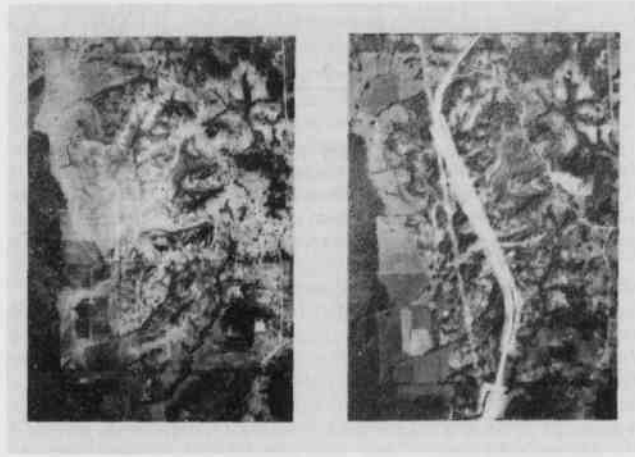

Figure 2. Aerial photos of Saratoga Landing Blackland Prairie area in 1951 (left) and 1964 (right). The area was substantially prairie (grazed) in 1951 and substantially forested in 1964. A powerline and a railroad were built between photographs. Cleared fields to the left are now in Millwood Lake. North is up in both photographs. Photos courtesy Soil Conservation Service.

VEGETATION OF AN INDIVIDUAL PRAIRIE

Woody Plant Cover

Woody plant cover on the 1/50 ha plots was estimated at 20.5% during the first sample period and declined after the fire to 15.0% (Table 1). This difference was not statistically significant.

Table 1. Woody plant cover. Years not significantly different ($p > .05$).

PLOT #	% COVER 1987	% COVER 1989
1	30	5
2	35	10
3	40	40
4	5	15
5	10	10
6	15	5
7	10	10
8	50	20
9	5	20
10	5	15
TOTAL	205	150
AVERAGE	20.5	15.0

Woody Plant Number

Woody plants were counted by species in the 1/50 ha plots (Table 2). The most abundant species was *Ilex decidua,* with an average of

The Vegetation of Saratoga Landing Blackland Prairie

Table 2. Numbers of woody plants in 0.02 ha plots. ILEXDECI = *Ilex decidua;* RHAMCARO = *Rhamnus caroliniana;* JUNIVIRG = *Juniperus virginiana;* BERCHSCA = *Berchemia scandens.*

PLOT #	ILEXDECI		RHAMCARO		JUNIVIRG		BERCHSCA		OTHER	
	-number-									
	87	89	87	89	87	89	87	89	87	89
PLOT 1										
<1.5m	2	2	0	11	0	0	3	11	32	41
>1.5m	0	1	1	2	0	0	0	0	0	1
PLOT 2										
<1.5m	1	4	2	7	0	0	5	0	28	10
>1.5m	1	2	4	2	0	1	0	0	0	0
PLOT 3										
<1.5m	8	9	1	11	4	0	12	3	20	0
>1.5m	13	20	1	3	8	3	0	0	11	15
PLOT 4										
<1.5m	28	12	0	3	2	0	0	1	11	3
>1.5m	7	3	4	3	2	0	0	0	1	1
PLOT 5										
<1.5m	32	21	0	2	2	0	11	0	0	0
>1.5m	9	2	0	3	5	2	0	0	0	0
PLOT 6										
<1.5m	34	4	4	2	5	0	30	0	5	0
>1.5m	8	11	4	3	4	0	0	0	3	0
PLOT 7										
<1.5m	15	14	1	5	0	0	48	0	0	2
>1.5m	9	12	3	7	2	0	0	0	3	1
PLOT 8										
<1.5m	10	8	2	6	7	0	19	2	12	4
>1.5m	15	9	7	7	3	0	0	0	0	0
PLOT 9										
<1.5m	8	5	4	8	13	0	34	16	11	1
>1.5m	4	0	2	8	17	2	0	0	2	2
PLOT 10										
<1.5m	22	17	5	8	2	0	22	5	0	0
>1.5m	8	15	3	6	3	4	0	0	0	0
TOTAL #										
<1.5m	160	96	19	63	35	0	184	38	119	61
>1.5m	74	75	29	44	44	12	0	0	20	20
Statistical Significance										
<1.5m	n.s.		**		*		*		n.s.	
>1.5m	n.s.		n.s.		*		-		n.s.	

160 plants per plot shorter than 1.5 m and 74 plants >1.5 m per plot. *Berchemia scandens* was more numerous in the size class <1.5 m. *Rhamnus caroliniana* and *Juniperus virginiana* followed in abundance. Several other species occurred in lower numbers.

The prescribed fire adversely affected many woody plants; however, susceptibility varied greatly. Smaller individuals of the most abundant species, *I. decidua,* decreased by 40% (not significant). However, individuals taller than 1.5 m increased slightly (also n.s.). *Rhamnus* showed a highly significant increase in numbers of smaller plants and a substantial (but n.s.) increase in larger individuals as well. *Juniperus* and *Berchemia* both showed significant declines; all red cedars <1.5 m were killed. The other species as a group declined, but not significantly.

Most woody plants were top-killed, but many resprouted by the time of the second sample. For instance, all individuals of *Ilex* in the <1.5 m size class were sprouts, and all but 4 in the >1.5 m size class were sprouts. Of *Rhamnus,* only 16 of the 63 individuals <1.5 m were not obviously sprouts, along with 6 of the 44 individuals >1.5 m. *Juniperus* did not resprout, and it was not possible to tell whether *Berchemia* sprouted. Among the "other species", *Campsis radicans, Fraxinus* sp., *Maclura pomifera,* and *Diospyros virginiana* all showed some sprouting; *Quercus muehlenbergii, Viburnum rufidulum* and *Carya myristiciformis* did not.

Areal Cover of Herbaceous Vegetation, Mulch and Bare Ground

Estimated cover within 0.25m² plots shows *Andropogon scoparius* to be the dominant species (Table 3). Herbaceous plants other than grasses (forbs) covered less than 10% of the plots. Fire reduced *Andropogon* cover from 57% to 23% (highly significant) and total forb cover from 8% to 5% (n.s.).

Table 3. Foliage cover of herbacious vegetation in 0.25 m² plots. ANDSCOP = *Andropogon scoparius,* BERCHSC = *Berchemia scandens.* TOTFORB = total forbs, MSGRASS = miscellaneous grasses, MSWOODY = miscellaneous woody plants, BAREGND = bare ground

	ANDSCOP		MSGRASS		TOTFORB		BERCHSC		MSWOODY		MULCH		BAREGND	
	-percent cover-													
PLOT	87	89	87	89	87	89	87	89	87	89	87	89	87	89
1N	50	20			10	10		5					40	65
1S	40	20			10	15		5					50	60
2N	80	20			10	5							10	75
2S	15	10			5								80	85
3N	30	0								15	30		40	80
3S	10	10			10			5		10	60		20	75
4N	80	50			5		5						10	50
4S	35	25			5	20			5		20			55
5N	65	5			10	20					15		10	75
5S	65	10	10						10	20	15		10	70
6N	65	30			10						20		5	70
6S	50	40			15	5	10	5			10		5	50
7N	70	10		10	15	5							15	75
7S	60	20			10			5			10		20	75
8N	70	40					10				20			60
8S	65	40				5					10		25	55
9N	80	15			5						15			85
9S	65	20			15	5		5			15		5	70
10N	65	30			20						15			70
10S	70	40			10	10		5			5		15	45
AV87	57		1		8		1		1		13		18	
AV89		23		1		5		2		2		0		67
STATISTICAL SIGNIFICANCE OF CHANGE BETWEEN YEARS														
	**		n.s.		n.s.		n.s.		n.s.		**		**	

Prior to the fire, mulch (dead organic remains) covered 13% of the plots. After the fire, essentially no mulch cover remained. Conversely, before the fire, bare ground covered 18% of the plots while after the fire, bare ground had increased to 67%. Both of these changes were statistically highly significant.

Biomass of Herbaceous Vegetation and Mulch

Biomass at the end of the growing season is dominated by *Andropogon scoparius* (Table 4). The effect of the prescribed burn on *Andropogon* production was dramatic, with a highly significant increase from 53.2 g/m² before the burn to 120.4 g/m² after. The only other significant change was that of mulch, which declined from 51.4 g/m² before the burn to 2.4 g/m² afterward. Total forb production increased from 15.1 g/m² before the burn to 20.7 g/m² after. Total current-year production (exclusive of mulch) increased from 71.0 g/m² before the burn to 146.7 g/m² after.

Table 4. Biomass of herbaceous vegetation in 0.25 m² plots.

	A. scoparius		Total forb		S. nutans		B. scandens		Mulch	
	-biomass in grams-									
PLOT	1987	1989	1987	1989	1987	1989	1987	1989	1987	1989
1N	12.50	17.33	9.37	16.48					7.95	
1S	11.90	16.76	3.69	18.18					13.92	
2N	17.04	38.92	5.11	1.99					17.90	
2S	14.49	29.54	4.83	13.07					14.77	
3N	15.06								68.46	8.07
3S	10.23	28.12							12.50	
4N	14.20	70.74	7.10							
4S	5.11	36.93	1.14	3.98					4.54	
5N	18.75	17.32	2.27	30.96					11.65	
5S	9.09	30.96	9.94						19.60	
6N	10.79	43.18	8.52						5.40	
6S	15.91	49.43					3.41	3.41	11.36	
7N	20.17	18.75	0.85		10.23	20.74				
7S	15.62	34.65	1.99						32.95	
8N	9.94	41.48								
8S	0.85	29.26							36.08	4.06
9N	22.16	28.98	3.12							
9S	4.54	23.86	3.12	3.12				3.98		
10N	25.00	19.89	10.51							
10S	12.50	25.85	3.98	15.62						
TOT	265.85	601.95	75.54	103.40	10.23	20.74	3.41	7.39	257.08	12.13
	-g/m²-									
AV	53.17	120.39	15.11	20.68	2.05	4.15	0.68	1.48	51.42	2.43
STATISTICAL SIGNIFICANCE OF CHANGE BETWEEN YEARS										
	**		n.s.						**	
TOTAL ANNUAL PRODUCTION:			1987 - 71.01 g/m²							
			1989 - 146.70 g/m²						**	

Forbs were not identified to species in 1987, before the burn. In the sample after the burn, forbs were identified and are shown in Table 5. *Dalea purpurea* was the most abundant species, occurring on 5 plots and averaging 12.4 g/m², about 60% of the total forb biomass. Although total forb biomass increased somewhat, forbs disappeared from 6 of the 15 plots in which they occurred before the fire.

Table 5. Biomass of forbs in 0.25 m² plots.

	Total forb		Forb Composition - 1989 Only		
	-biomass in grams-				
PLOT	1987	1989	D. purpurea	Other - species	
1N	9.37	16.48	16.48		
1S	3.69	18.18	13.35	Rudbeckia hirta	4.83
2N	5.11	1.99	1.99		
2S	4.83	13.07		Grindelia lanceolata	13.07
3N					
3S					
4N	7.10				
4S	1.14	3.98		Rudbeckia hirta	3.98
5N	2.27	30.96	14.77	Liatris aspera	16.19
5S	9.94				
6N	8.52				
6S					
7N	0.85				
7S	1.99				
8N					
8S					
9N	3.12				
9S	3.12	3.12		Acacia angustissima	3.12
10N	10.51				
10S	3.98	15.62	15.62		
TOT	75.54	103.40	62.21		
		-g/m²-			
AV	15.11	20.68	12.44		

SUMMARY AND DISCUSSION

Saratoga Landing Blackland Prairie Natural Area was substantially covered with prairie at the time of settlement, with encroachment and invasion by woody vegetation occurring fairly recently (after 1951). Woody plant cover on a prairie within the natural area was about 20% in 1987. At that time, *Ilex decidua* was the most common woody species, following by *Berchemia scandens, Rhamnus caroliniana, Juniperus virginiana* and others of lower abundance. The dominant grass was *Andropogon scoparius,* with 57% cover and 53.2 g/m² net production over the growing season. Dead organic remains (mulch) covered 13% of the ground and contained 51.4 g/m² biomass. Bare ground had an areal cover of 18%.

In March of 1989, a prescribed burn of the prairie was conducted. In September of that year vegetation was again sampled. Total woody plant cover had decreased slightly (not statistically significant); species response was variable, and resprouting was common. *Juniperus* and *Berchemia* declined significantly; *Rhamnus* increased significantly, apparently due to prolific resprouting; others did not change significantly. However, most woody plants were top-killed; resprouting masked the adverse effect. Among herbaceous plants, seasonal net production doubled. However, the 146.2 g/m² annual production was only about 18% of that reported by Irving (1980) for a prairie in the Grand Prairie of eastern Arkansas, and 29% of that reported by Diamond (1980) for the Fayette Prairie, an outlier of the Texas blackland prairies. Mulch virtually disappeared and bare ground nearly quadrupled to 67%. The increase in bare ground was also contributed to by *Andropogon,* which decreased in cover at the same time it increased in biomass. Apparently basal leaves were reduced as culms became taller.

Most woody plants were adversely affected by the one prescribed fire, but most resprouted. Repeated fires will probably kill most woody plants. Both the response to the controlled fire and examination of aerial photos indicate that fire was important in maintaining these prairies prior to 1951, at which time effective fire supression may have become established. Grazing pressure may also have been reduced at that time. Removal of mulch and increase in area of bare ground by fire may accelerate erosion on these sloping sites, and frequent wildfires probably contributed to the eroded areas that exist on the blackland prairies. Prescribed fire appears to be an effective technique for managing these prairies, but should be undertaken cautiously because of the potential for erosion.

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STUDY OF DEPOSITION METHODS FOR SILICON POWDER

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ABSTRACT

Silicon powder tends to agglomerate at normal atmospheric conditions and is, hence, difficult to aerosolize. Several methods of aerosolizing silicon powder and finally depositing it on various substrates were investigated. This paper presents the investigated methods of aerosolization. The electrostatic spray coating used in dry paint application was found to be the most suitable. The general merits of this method and its use for silicon powder deposition to form films are discussed.

INTRODUCTION

Thin film deposition of silicon is very important in its applications to solar cells and integrated circuits. The conventional deposition methods are many, but the most prevalent include sputtering, chemical vapor deposition (CVD), and molecular beam epitaxy. The required equipment for these processes is extremely expensive, which affects the finished product cost. Though solid phase deposition and subsequent annealing is used in other industries, it has not been applied to silicon deposition. The technique was successfully applied to silicon film deposits, and could offer significant cost reduction relative to current methodology. Metallurgical powders (Kirk and Othmer, 1981) as well as polymers (Rodriguez, 1967) have been coated on substrates by electrostatic spray application (Miller, 1987). Other methods such as plasma and thermal spraying have been used to deposit ferrites, samarium-cobalt permanent magnets, and ceramic oxides (Kumar, 1988; Kumar and Petrovitch, 1988; Varacalle Jr., *et al.*, 1988). This research focused on using solid phase deposition of silicon powder. Several methods of aerosolizing and depositing the powder were conducted. The most successful results were obtained through electrostatic charging and deposition of silicon on conducting, semiconducting, and insulating substrates. Excellent deposition uniformities have been obtained.

METHODS

DEVELOPMENT OF AN AEROSOL DEPOSITION TECHNIQUE

An appropriate aerosol generation technique has been developed where particles could be either charged or uncharged. Some of the critical considerations for generating the aerosols were to: 1. avoid agglomeration, 2. minimize losses due to deposition on flow tube walls, 3. minimize pickup of contamination, 4. obtain good uniformity of deposition, and 5. obtain repeatability.

Several methods were investigated to aerosolize the silicon powder and deposit it uniformly. These methods utilized fluidized bed, dust feeder, acoustic feeder, and vibrating dispenser techniques among other methods. All these methods have been discussed in detail below. The highest purity of silicon powder available was 99.999% pure silicon as purchased from CERAC Inc. The size analysis was done using a Coulter counter. It was noted that the arithmatic mean diameter was 22.90 micrometers, geometric mean diameter was 17.22 micrometers with a geometric standard deviation of 2.6. Another powder whose average diameter was 5.05 micrometers also was used. The distinction between the two has been made wherever they have been used. A step by step discussion of the methods used to generate the aerosols follows.

FLUIDIZED BED METHOD

As shown in Fig. 1, a fluidized bed was used to generate the aerosol with subsequent deposition on the stages of a 6 stage cascade impactor. This method caused the clumps of particles to form on the bed without aerosolization unless high flow rates (>30 LPM) were used. When very high flow rates were used, the problem of particle bounce was magnified. The cascade impactor is used generally for size distribution analysis. If particles could be size-separated, then substrate deposition of a particular sized particle from a polydispersed aerosol would be made easier by simply adding or subtracting a stage. Only a small quantity of particles entered the cascade impactor because most of the clumps could not be aerosolized at the flow rate compatible with the design requirements of the cascade impactor. Some results that were obtained are described below.

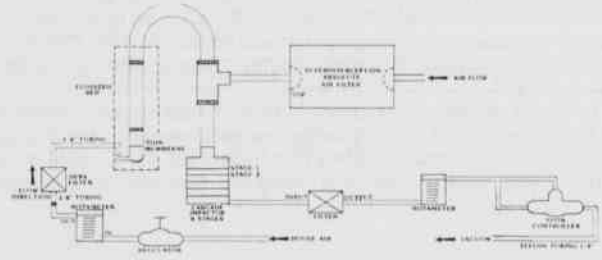

Figure 1. Schematic of the fluidized bed method.

DATA AND OBSERVATIONS

A controlled supply of house air was supplied to a fluidized bed. Silicon dust (−325 mesh or 44 micrometers and smaller) was aerosolized and collected on the 6 stages of our Sierra Series 210 cascade impactor. A cascade impactor filters out particles based on their size by virtue of its filter openings and the flow rate. The filters were weighed before and after collection and the mass percentage was calculated. Typical results are shown in Table 1.

When the flow rate was 14 lpm, the first stage filtered out 13 micrometers and greater particles, the next stage 7.8 micrometers and greater, the third stage filtered 3.1 micrometers and greater, and so on. The last stage filtered out particles 0.63 micrometers and less. When

Table 1. Size analysis on 99.999% pure silicon (−325 mesh).

Flow Rate = 14 lpm

Stage of Cascade Impactor	Cummulative Wt% Collected	Size (um) of Particls
Stage 1	86.61	> 13
Stage 2	91.38	> 7.8
Stage 3	95.83	> 3.1
Stage 4	96.46	> 1.8
Stage 5	96.46	> 1.2
Solid/Stage 6	99.96	> 0.63

The above data are suspect since clumps comprised of finer particles which aerosolized were trapped on the top. However, it provides a rough estimate of the amount of particles in different size ranges.

the flow rate through the cascade impactor was changed, the different stages trapped a different particle size distribution.

The smaller the particle, the better the deposition uniformity. However, particles smaller than 0.63 micrometers are observed from Table 1 to be 0.04%. Thus, they constituted a minor fraction of the total powder that was deposited. One major problem was that of the 85 mg of silicon powder in the fluidized bed, only 3.5 mg was aereosolized even after 30 minutes at an air flow of 14 lpm. The reason was that the silicon powder was very dense and tended to form clumps. This method using a fluidized bed was discontinued.

DUST FEEDER METHOD

A dust feeder replaced the fluidized bed as shown in Fig. 2. A dust feeder has a higher entrance and exit velocity per unit flow rate due to smaller dimensions on the inlet and exit streams. The higher velocity caused the particles to be easily aerosolized. However, 45% by mass of particles deposited on the walls of the flow tube and only 10% of the total powder reached the cascade impactor. The objective was to flow as much powder as possible through the cascade impactor. Since only 10% ever made it to the cascade impactor, this method would not be economically feasible. Data and observations are described below in greater detail.

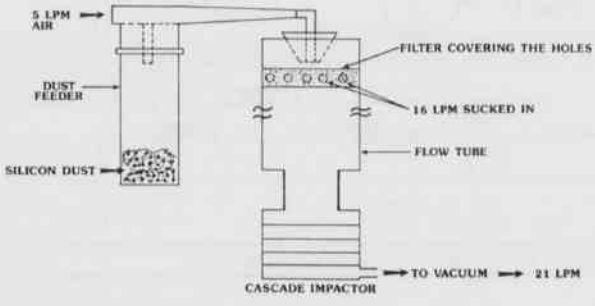

Figure 2. Schematic of the dust feeder method.

DATA AND OBSERVATIONS

Due to the high velocity of entering air, turbulence is created and the lighter particles get fluidized and leave the bottle at high velocity. A large diameter tube with holes on the top covered by a filter was used to blend in additional air to decrease the flow into the cascade impactor as shown in Fig. 2. As the powder was being aerosolized, a lot of it visually was observed to be depositing on the walls of the plastic tubing. The particles tend to develop triboelectric charge and since PVC and plastic are insulating, the particles deposit and stick on the wall. Also, a static guard spray was used to coat the inside of the tube. The result was no different. Approximately 10% collected in the cascade impactor. The spray guard caused the plastic to crack in the area where holes were drilled into the plastic. Initially the flow rate was 14 lpm, but later increased to 21 lpm where more of the dust appeared to aerosolize. A copper tube with holes drilled on the top also was tried to alleviate the triboelectric charging of the silicon. Again, only 10% was collected in the cascade impactor. Table 2 shows the significant results of the experiments and the conclusions reached.

Table 2. Results of the experiments discussed in dust feeder method.

Expt. #	Starting Mass of Silicon (mg)	Mass on the 6th Stage of Cascade Impactor	% Passed Into Cascade Impactor	Vacuum LPM	Flow Rate LPM	Time	Observations and Info.	Flow Tube Material Comments
1	689.7	64.33	9.32	22	16	3	Non-Uniform Deposition	Plastic
2	665.1	70.6	10.61	21.5	16	3	Deposition inside copper tube not clearly observable	Copper
3	920.5	N/A	10.49	22	16	5	Static guard used & uniform deposition of powder obtained on inside walls	Plastic (45% collected in flow tube)

Conclusion 1) particles were charged and particle repulsion caused them to deposit on the wall.

2) when the different stages were observed under an optical microscope many clumps were found on the different stages indicating particle bounce, hence, use of cascade impactor was discontinued.

ACOUSTIC METHOD

In this method, the specific problem of clumping was addressed using an acoustic technique. Figure 3 shows the experimental design. A sierra dichotomous sampler was used to separate the fine from the course particles and direct them into a depositing chamber of a TSI 3100 electrostatic precipitator. The acoustic frequency was 3.5 kHz. A substantial amount of aerosol passed through the sieve, but too much powder placed on the sieve caused it to clog, making this method of no use. The flow through the TSI 3100 electrostatic sampler was maintained at 5 LPM (connected to house vacuum and house air). The particles were deposited on a microscope cover slip and when observed under the optical microscope, their size was 2.5 micrometers or less; this confirmed that dichotomous separation was occurring. Very sparse distribution of particles was observed, however, since very few particles in the aerosol were 2.5 micrometers and less. The major drawback was that the acoustic generator did not deliver a controlled mass flow of particles, but generated spurts. A powder feeder which dropped powder onto the sieve was developed and tried with limited success. Another drawback was the high acoustic levels that were generated, but which were necessary to break any clumps that formed on the sieve. Hearing protection was required and work had to be done in off-hours for the safety of the laboratory workers. This method was not of much use since there remained a problem of control over generation of aeosol. It was decided, therefore, to further characterize the behavior of the powder under the influence of an electric field.

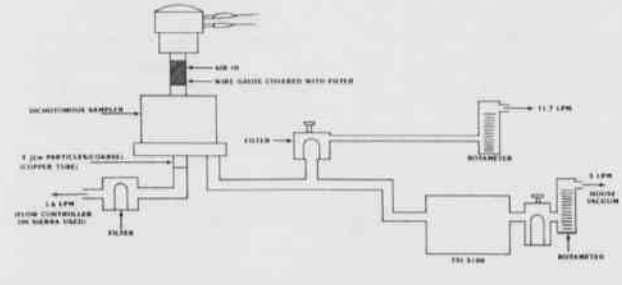

Figure 3. Schematic of the acoustic method.

ELECTRIC FIELD METHOD

Two electrodes were placed into a transparent plastic tube. A dust feeder was used as shown in Fig. 4. It was established from the results in the dust feeder method, Experiment #3, that about 55% of the powder was aerosolized from the bottle and 45% of the total was deposited on the walls of the plastic tube. Hence, the electrodes were placed approximately 5 to 6 cm below the inlet of the dust feeder. One electrode was grounded while a positive charge was placed on the other. The potential was first held at 750 volts DC. Powder deposited on the plates, but not in significant amounts, and the powder flaked easily when deposited on a coverslip and slides. Most of the deposition took place at the bottom end of the electrodes (due to aerodynamic effects). The DC voltage was increased to 3000 volts. This caused the powder to deposit selectively on the positively charged electrode with very little powder depositing on the ground electrode; this showed that the silicon powder was capable of acquiring charge and responding to an electric field. Observations under the Shadow Graph showed fairly thick powder deposition. The particles acquired triboelectric charges.

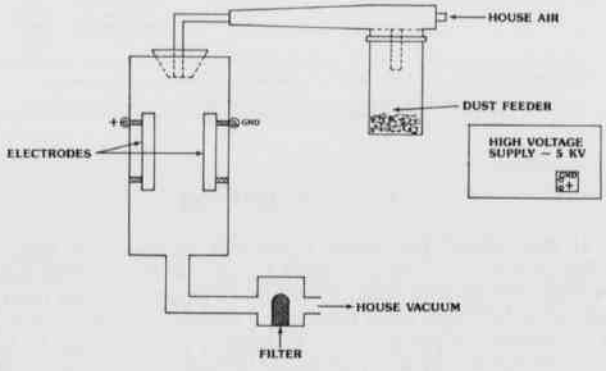

Figure 4. Schematic of the electric field method.

VIBRATING POWDER DISPENSER METHOD

As an extension to the electric field method, a vibrating engraver was used to transfer its vibrations to a powder holder. This is shown in Fig. 5. The base of the powder holder was a 50 micrometer sieve. Particles flowed through the sieve and glass beads were added to break clumps. The voltage did not effect the powder deposition when the aerosol was generated using this method. This was attributed to insufficient charging of the powder.

Although the powders were not initially charged in both methods, the powder still seemed to acquire charge in the electric field method and not in the vibrating dispenser method. In this method, the particles were not subjected to any bulk attrition, which was the reason the particles were not charged and, therefore, not responding to high electric fields as in electric field method.

As in the other described methods, this method also had its share of problems in generating a uniform powder dust. However, one very important point that was noted between the electric field method and this method was that the silicon particles acquired charge depending on the method used and could retain it until they deposited. This important information was utilized in the next experiment.

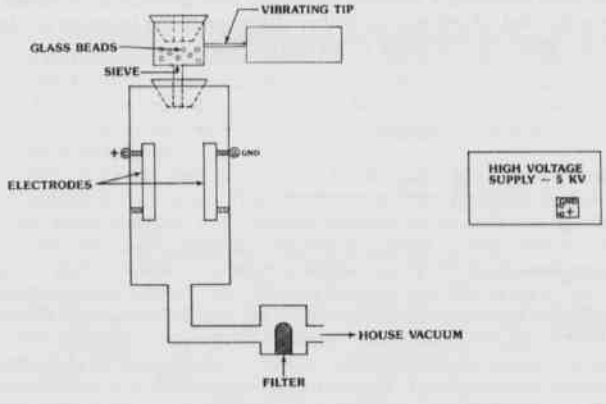

Figure 5. Vibrating powder dispenser method.

ELECTROSTATIC SPRAY DEPOSITION METHOD

Ameron Powder Coating Company in Little Rock is using an electrostatic spraying method to deposit paint pigments on metal substrates that are subsequently heat treated to produce the required finish. A typical powder coating system required the following components: 1. the powder feeder unit, 2. electrostatic powder spray gun, 3. electrostatic power source, and 4. overspray recovery unit.

The powder was supplied by either fluidization or gravity feeding to the spray gun. The flowing gas is generally air which helps in easier transportation and charging. Volume and velocity of the powder flow can be adjusted. The gun used in this research is an external corona charging gun as shown in Fig. 6. The thickness of deposition is controlled by the position of the spray gun, length of spray time, velocity of powder flow, and electrostatic charge level. Silicon powder was introduced into the Ransberg-Gema (Model #706) electrostatic cup gun through a hopper and sprayed. The gun voltages selected ranged from 0 to 100,000 volts DC. Experiments were conducted and the best gun voltage to obtain uniform deposition was found to be 75 kV. Data and details of the above mentioned experiments and technical details on the gun are described below.

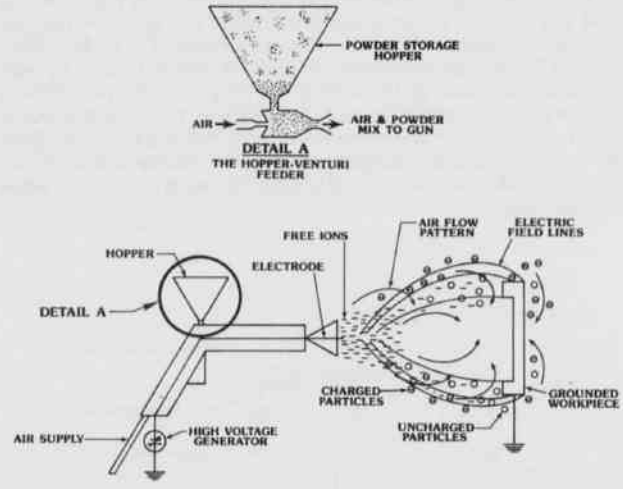

Figure 6. Elecrostatic spray deposition method.

RESULTS AND DISCUSSION

Table 2 shows the results of experiments performed to study the effect of gun voltage on powder deposition and chargeability (coulombs/kilogram). The silicon powder used in this study had a count

median aerodynamic diameter of 5.05 micrometers and a purity of 99.999%. The complete size distribution plot obtained by ESPART analysis is shown in Fig. 7. This was the same powder that was obtained after grinding the original 22.90 micrometer powder. Figure 8 shows the results of the effect of gun voltage on the charging ability of the powder. The limiting charge on a spherical particle called the Pauthenier limit (Pauthenier and Moreau-Monot, 1932) is given as follows:

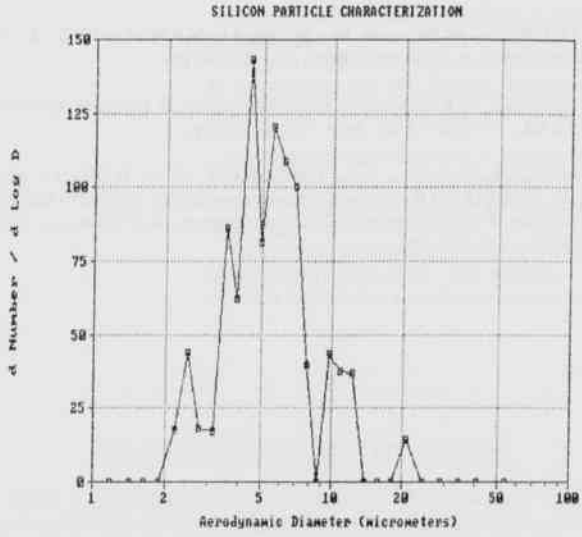

Figure 7. Frequency distribution curve (logarithmic size scale) of ground powder.

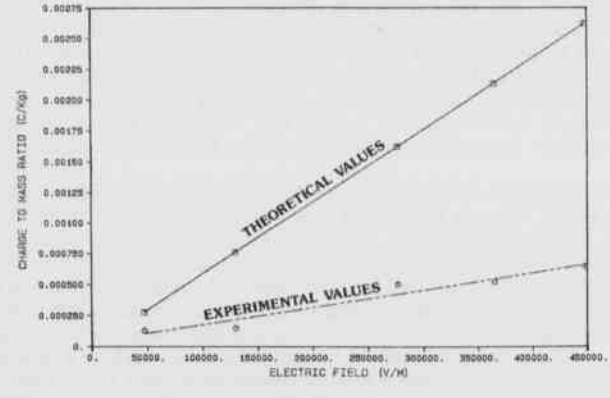

Figure 8. Effect of gun voltage on chargeability of 5.05 μm, 99.999% pure silicon powder.

$$q = 4\pi r^2 \epsilon_o BE$$

where r = particle radius; ϵ_o = permitivity of free space; and E = electric field strength.

$$B = 1 + 2\frac{\epsilon_r - 1}{\epsilon_r + 1}$$

where B = 2.69 for silicon powder and ϵ_r = relative permitivity of silicon (11.8). Hence, the limiting charge to mass ratio will be

$$q/M = \frac{3\epsilon_o BE}{rd}$$

where d = density of silicon (2440 kg.m^{-3}). B = 2.69 for silicon powder and ϵ_r = relative permitivity of silicon (11.8)

The theoretical values and experimental values are plotted in Fig. 8. The increasing value of electric field indicates increasing gun voltage. Experimental values were lower due to the low charging efficiency of the corona process.

This experiment was done using a fully grounded Nordson aluminum booth as background during spraying. Due to this background, although the gun was set for maximum voltage (100 kV), the voltmeter deflection read 75 kV. The charge acquired per kilogram of particles was determined using a Sheen electrostatic spray diagnostic instrument.

Since success was achieved in depositing these powders and it was established that the silicon powder was charging, it was decided to discontinue development of any of the previously mentioned methods and concentrate research using this method. N and P doped silicon wafers (Monsanto Electronic Materials Corporation-MEMC), single crystal insulating sapphire wafers, and metals were used as substrates. Very good powder coatings were achieved.

TECHNICAL INFORMATION ON RANSBERG GEMA (MODEL #706)

The GEMA 705 (100 kV) powder container: Capacity: 0.8 litres.

TECHNICAL DATA

Pneumatical data

Maximum input pressure:	12 bar
Optimum input pressure:	6 bar
Maximum water vapor content in compressed air:	1.3 g/Nm^3
Maximum oil vapor content in compressed air:	0.1 ppm
Maximum compressed air consumption	11.2 Nm^3/h

Electrical data

Power supply:	
Single-phase AC current, selectable voltages: 100 V (+10%,-15%).	
Frequency: 50/60 Hz	
Connected loads:	40 VA
Temperature range:	+10 °C to +50 °C
Nominal input voltage:	10 V eff.
Frequency:	17000 Hz
Nominal output voltage:	100 kV
Nominal output current:	0.07 mA
Maximal output current:	0.15 mA
Polarity:	negative

Lengths of powder hoses and connecting cables

Connecting cable:	5.5 m
Powder hose:	5.8 m

Powder throughput: Maximum powder throughput depends on the length of the powder hose and the type of powder.

CONCLUSION

The electrostatic spray deposition method using the Ransberg Gema (Model #706) gun has been established to be the best method among the methods investigated for uniform silicon deposition. The gun voltage needs to be at least 75 kV. Silicon powder has been coated on conducting, insulating, and semiconducting substrates.

ACKNOWLEDGMENT

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ENGINEERING: ART, SCIENCE, OR TRADE

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ABSTRACT

Several definitions of the term "engineer" are presented, discussed, and contrasted with the term "scientist". These definitions demonstrate the fundamental differences between engineers and scientists and their professions. The engineering method is compared with the scientific method and the value of each is discussed.

Several aspects of engineering education are covered. The need for more liberally educated engineers is emphasized and the impact of computers on engineering education and the engineering profession is discussed. The value of a good science foundation in an undergraduate engineering program is also stressed.

An engineering education is only as good as the engineering educators and for this reason it is imperative that the best engineers be involved in education. This is especially true in engineering design courses. Practicing engineers with practical experience must be brought into the education arena to share their experiences.

Engineering and science are different professions. Each has a different set of goals and different methods of achieving these goals. This division or separation of science and engineering serves the best interest of each profession and also mankind as a whole.

ENGINEER AND SCIENTIST DEFINED

What is an engineer? What is a scientist? The answers to these very basic questions can bring to light the fundamental differences between the two. Unfortunately there are few, if any, clear cut definitions of an engineer or a scientist. The few definitions that can be found do little to clarify the distinction and they do not recognize that there are certain areas in which the two overlap.

An engineer can typically be defined as a person who deals with artifacts rather than theory. An engineer designs artifacts such as bridges and machines, and he also analyzed artifacts and processes, such as the heat transfer in a boiler or the stress in a piston arm. A scientist, on the other hand, deals with facts and theories; his job is to expand the knowledge base through derivation and experimentation. A scientist only deals with things (artifacts) in the process of deriving or testing new facts or theories.

The dictionary, a standard reference for definitions, does little to give precise meaning to the terms. The *Oxford English Dictionary* defines an engineer as, "One who contrives, designs, or invents; an author or designer. Or, one whose profession is the designing and constructing of works of public utility, such as bridges, roads, canals, railways, harbors, drainage works, gas and water works, etc."

The masthead of *The Structural Engineer* states that structural engineering is the science and art of designing and making with economy and elegance, buildings, bridges, frameworks, and other similar structures so that they can safely resist the forces to which they may be subjected. This definition points out 3 important aspects of engineering: that engineering is both art and science; that engineering combines elegance and economy in artifacts; and that engineering is concerned with safety.

The National Research Council's Committee on the Education and Utilization of the Engineer defines an engineer as a person having at least one of the following qualifications: a. college/university B.S. or advanced degree in an accredited engineering program; b. membership in a recognized engineering society at a professional level; c. registration or license as an engineer from a governmental agency; or d. current or recent employment in a job classification requiring engineering work at a professional level (National Research Council, 1985).

The *Oxford English Dictionary* defines a scientist as, "A man of science." Science is defined as, "The state or fact of knowing; knowledge or cognizance of something specified or applied."

These definitions serve to illustrate that an engineer deals with artifacts whereas a scientist deals with facts. They point out that although an engineer uses science in his work, it is a tool. It is a mistake to consider engineering as applied science. Engineering is no more applied science than science is basic engineering — the two are distinct. If engineering is taken as the building of artifacts then the early engineers were primarily artists (Liebman, 1989). Early man did not analyze and hypothesize a slingshot, he engineered it. He learned from making slingshots how to make better slingshots. Science came along much later.

Engineering is a creative process. There is no book of designs that an engineer can go to and pull out a solution. True, parts of certain designs are well known and documented, but the use of these parts to create a whole usually involves creating new parts.

Engineers deal with artifacts; they may be physical objects or processes. The engineer first uses his imagination to create the artifact in his mind — he pictures it. Once the artifact has been imagined the analysis and refinement of the artifact can begin. Science is really thinking 'on second thought', and science is applied 'after the artifact', when the object has been pictured first in the mind of the engineer (Petroski, 1990). This is not to say that engineers only imagine artifacts and do nothing else, nor does it say that engineers are the only ones who have creative ideas. Engineers not only have ideas but they make them work to benefit mankind. This was summed up nicely in a recent theme of National Engineers Week — "Engineers: Turning Ideas Into Reality".

Engineering is the art that deals with materials and material forces and its purpose is to serve mankind. Pure science typically deals with fewer variables than does engineering. Science attempts to discover the fundamental facts about materials and phenomena (Cross, 1952).

The engineer, and more generally the designer, is concerned with how things ought to be — how they ought to be in order to attain goals, and to function (Simon, 1981). Science, on the other hand is concerned with explaining how things are and how they operate. Science is the study of what is; engineering is the creation of what is to be (Waldron, 1989).

Engineers tend to be makers — they make artifacts to accomplish certain goals. Engineering is the uniting of craft and science to develop artifacts (Petroski, 1990). They try to make the best artifact at the lowest cost. To the scientist, the final goal is the addition of new facts to the knowledge base. He is not concerned with the production of artifacts, just the attainment of knowledge. However, the scientist may, in his quest for answers, develop a new apparatus to aid him in his search. Likewise, the engineer, in his development of a new artifact, may discover a new fact. This indicates there is a certain overlap of science and engineering.

METHOD

If science and engineering are truly different professions then this would be indicated in their respective methods. A close examination of both scientific and engineering methods does indeed reveal different premises, different expectations, and different attitudes. Often the engineer is thought of as an applied scientist — one who simply applies scientific laws to real world problems. But this reduces engineering to a mechanized process and ignores the creative aspects inherent in design.

The fundamental activity of science, and therefore of scientists, is to make observations. These observations are made carefully and without bias; they are then analyzed by the scientist to find similarities or differences. The ultimate goal of the scientist is to develop a theory or law which will not only explain the observations, but will predict future behavior. The theory, law, or hypothesis can never be proven correct. The theory may be used for centuries, accepted as true by everyone, but never proven. The theory can, however, be proven incorrect by just one example of some behavior which is contradictory to that predicted by theory.

The scientific method recognizes that theories can never be proven correct but can be proven incorrect. A scientist makes every attempt to disprove his own theory. If, after much effort, the scientist has not disproven his theory he will open it up for attack by his peers. His peers will attempt to disprove the theory, not because they are mean-spirited disbelievers, but because they recognize that a theory can only be disproven, never proven.

In contrast to the scientist who attempts to explain nature, the engineer attempts to use nature to effect change. The engineer does not attempt to explain how things work; he makes things work. While science explains the law of gravity, engineering allows man to overcome gravity and to walk on the moon. The engineer does not try to find the one correct solution but tries to find the best solution. The best solution is relative and depends on numerous factors: time, place, economics, and of course, problem definition.

The engineering method is defined as the strategy for causing the best change in a poorly understood or uncertain situation within the available resources (Koen, 1985). This is perhaps the best definition of the engineering method because it incorporates several aspects unique to engineering; it mentions the best change, not the only change or the correct change. The definition also points out that there are limited resources and that the problem is not always well defined or fully understood.

Unlike the scientist who must carefully lay out a path and follow it to demonstrate his theory, an engineer is not bound by this method. Engineers do not rely on pure, basic facts, they rely on analyses, tests, experience and common sense (Cross, 1952). This is not to say engineering is haphazard and undisciplined; it is not. Engineers must consider many aspects of a problem and its solution, many of which offer conflicting or contradictory evidence. The engineer must sort through this, justify his assumptions, and make sure if he errs, he errs on the side of added safety.

There is no single step-by-step method for engineers or scientists to use in solving problems or developing theories; each individual has his own method and frequently it varies from problem to problem. There are, however characteristics common to each method. These definitions indicate the fundamental difference between engineers and scientists, indeed between engineering and science. Whereas the scientist puts forth his theory to be proven incorrect, the engineer puts forth his solution on the basis that it will not be proven incorrect — that it will function as intended. Each method is well suited to its respective subscribers and serves them well; however, the use of the scientific method to solve an engineering problem would be impossible, and the use of the engineering method to develop a scientific theory would be disastrous.

EDUCATION

Engineering is a profession that is practiced openly, with interaction from people and society. Engineering decisions and designs have an effect on individuals, if not on society as a whole. This is an aspect of engineering not shared with science. Science has had a profound effect on society and many ills have been produced by both good and bad science, but science is not concerned with social consequences (Harris, 1983). Although a scientist may develop a new plastic or discover a fundamental law of nature, this seldom affects society directly. It may have a profound effect on society when an engineer uses or misuses the new plastic or law in the design of a product, but this is due to engineering decisions and not due to scientific revelations.

Engineers are often placed in positions of deciding what 'best' is: what is best for society, what is best for a company, or what is best for the environment. Obviously their decisions affect the economy, environment, public policy, and people. Examples of how engineers and their decisions affect these areas can be found in ballistic missiles, automobiles, and the explosion of the Space Shuttle Challenger. These are but a few of the numerous ways in which engineering affects our lives. Some engineers are unaware of how they and their decisions will affect society as is evidenced by the recent catastrophic failures of the Hyatt Regency walkways, and the numerous EPA Superfund cleanup sites.

Engineering curricula need to be changed to allow engineering students to be exposed to more courses in liberal arts and social sciences. The result will not only be a better educated member of society, but a better engineer. Psychology and sociology will help the future engineer understand who he will be dealing with and how to deal with them. More courses in art will help the student appreciate aesthetic beauty and possibly design a nicer looking bridge. Engineering is, at one level, art. The creativity exhibited in the conception of an engineering design is similar to that exhibited by a painter or sculptor in the conception of their work. By requiring more true art courses in the engineer's undergraduate curriculum his creativity can only be improved.

In practice, engineers find themselves wrestling with many ethical decisions — something which most were not prepared for in school. There are no right or wrong answers in engineering ethics, only good or bad ones. Many times ethics cannot provide an answer, but can serve to clarify the issues involved, thereby influencing the final engineering decision (Gunn, 1990). Engineering students need to learn that all problems, especially ethical problems, do not necessarily have a solution. Undergraduate engineering students could learn this if they were exposed to real ethical decisions by those who make them — practicing engineers. Engineering professors with nothing but academic experience are only in a position to teach what they read. A practicing engineer, or a professor with practical experience, is in a position to share what he has lived and to discuss the difficult decisions he has made. At the very least, a student should not receive his degree unless he understands he is serving society first, his employer second.

Few, if any events have had a greater effect on engineering and engineering education than the development of the computer. By using a computer, an engineer can solve complex problems in minimal time. Drawings can be made, modified, and stored at speeds unheard of before the computer age. Productivity can be greatly increased by the proper use of a computer; unfortunately, improper computer usage can result in decreased productivity and dangerous designs.

Recognizing the value of the computer in engineering, engineering education has incorporated the computer into its curricula. Placing too much emphasis on computers can have disastrous results and, unfortunately, this seems to be the way engineering education is going. More and more, students are expected to solve problems on a computer by trying several iterations and giving a precise four-digit answer. Rather than solve an equation for χ, they solve it by trial and error using a computer. There are several dangers in using this approach to computers — especially at an early stage in a student's education. First, it encourages the notion that any problem can be solved given enough computer time to execute enough iterations. Second, it encourages the student to expect one, precise, accurate answer. The student can forget that the data he uses are seldom accurate or precise — just close.

Computers, combined with the numerous software packages available, can give an engineer a false sense of security and allow him to tackle problems beyond his experience. Unless caution is exercised in all phases of design, disasters can result. The Hartford Civic Center is one such failure directly attributed to an engineer using a computer with software to design a structure far beyond his limits of understanding

(Petroski, 1985). Computers must be used in engineering; many of the problems engineers are required to solve today are too lengthy and complex to be done without a computer. But the answers given by computers, like the answers given by the slide rule and calculator, must be checked by basic, fundamental laws and equations of engineering; they must be tempered by engineering judgment and experience. By encouraging or requiring students to implement computers early in their educations, the students are given the message that everything done on a computer is better and more accurate than something done by hand. Students need to be taught that back-of-the-envelope and graphical solutions are quite valid and frequently more convenient than computer solutions. Teaching students rules-of-thumb will give them additional tools to verify computer solutions and give them the ability to solve problems in the field or get a "ball park" answer when pressed for time.

Although an engineer should receive a well rounded, liberal education, science courses should not be ignored. Science is one of the engineer's most important tools and a firm foundation in the fundamentals of science will prove invaluable. But the engineering student must learn that science is a tool and nothing more. Science is to be used with experience, tempered by an appreciation for art. Often an engineer's instinctive feeling is a better indicator than scientific data. The cause of the Challenger explosion was due, in part, to an engineer not having, in his opinion, conclusive data on O-ring erosion (Whitbeck, 1987). The available data, although not necessarily conclusive, did indicate a problem and that in itself should have been enough for the engineer to recommend against the launch. The contributing factor in the disaster was an engineer seemingly forgetting his ultimate responsibility to protect the safety of the public, and not looking at the available data with enough suspicion.

To achieve the goal of providing a well-rounded, liberal education to engineers and to provide them with the needed foundation to deal with ethical problems, 2 things need to be considered. First, thought should be given to extending undergraduate programs from 4 to 5 years (National Research Council, 1985). This additional time would allow for more humanities courses to be taught and would give the students a chance to explore areas which interest them while not detracting from the very important technical education. It would be a rigorous curriculum, and would involve hard work on the part of the student. It would also impress upon the students that engineering is hard work and the best engineers are the ones who work the hardest. A 5-year curriculum would also address the fact that it is rare for a person to go through an engineering curriculum in the prescribed 4 years.

Second, engineering educators should be given the opportunity to practice engineering before teaching it. Engineering started as an art then evolved into a trade. The first engineering education system consisted of an apprentice working for an experienced person. The apprentice learned engineering by doing and learned from the mistakes made by his employer. This system, however, was soon found to be inadequate and formal engineering schools were established in order to educate students in the humanities and sciences. A formal education gave the engineer the ability to solve new problems using new methods. The pendulum has now swung the other way; we are forgetting our roots as artists and craftsmen and are replacing experience with education. Inadequate funding is forcing a decline in both quality and quantity of engineering laboratory courses. Now some of our most respected engineers, those with doctorates, have never practiced engineering. They have gone from high school through graduate school, never taking the time to be an engineer. The current process of education tends to produce excellent researchers but does not necessarily produce excellent practicing engineers. Some people go so far as to say that engineering faculty who only teach are not considered to be practicing engineers (Hazelrigg, 1988).

The practice of engineering allows an engineer to learn theory by using it and recognizing its limits. Practical experience can be invaluable to an engineering educator, especially one who teaches design courses. No one would suggest allowing surgery to be taught by someone who has never held a scalpel outside of class, yet we routinely allow engineering design to be taught by those who have never designed anything outside of academia. Perhaps it is time to reconsider the necessity of a Ph.D. to teach design and consider the requirement of experience, A B.S. or an M.S. level engineer with years of design experience may be better qualified to teach design than the Ph.D. with experience limited to academia.

Another method of getting practical engineering experience in the classroom is to bring in practicing engineers for a short time. Engineers working in industry, government, or private practice have valuable knowledge and practical experience they can share with students. This sharing can be accomplished by allowing these engineers to come into the classroom and teach some engineering design courses for a semester or even for a few weeks. At the same time, the engineering professor could fill the role of the practicing engineer. The professor could gain some practical experience by working in the practice of engineering and not just in education or research.

CONCLUSIONS

Engineering and science are fundamentally different endeavors. Where engineers design artifacts and find new uses for materials to benefit mankind, scientists seek truth, seek to explain nature. Each profession makes use of the other; the engineer uses science in his solution of a problem and the scientist often uses some engineering in his work. The danger comes when the engineer and the scientist confuse who they are and what they do. The engineering educator who has followed the path to a Ph.D. without gaining practical experience often confuses engineering with science.

To adequately solve problems that are presented, an engineer needs to consider all aspects of the problem including sociology, economics, and at times, even religion. To be prepared for this task, the engineer must have a more liberal education and it may require 5 years of schooling. The engineering student also needs to learn from experienced, practicing engineers in addition to the traditional research oriented Ph.D. engineering educators commonly found at universities.

Engineering is a unique blend of science, art, and trade. We all have engineering roots as evidenced by man's first use of tools, but today an engineer is determined by how he works, not what he produces. Many people have produced beautiful and useful artifacts, but these pepole are skilled craftsmen, not engineers. They lack the requisite ability and knowledge to analyze. They achieve their goals by the expensive and potentially dangerous process of trial and error. The engineer usually does his trial and error on paper and eliminates many designs before anything is constructed. The engineer still has failures — due in part to his mistakes, in part to the imprecision of engineering itself. The truly good engineer, one interested in bettering himself and his profession, analyzes the cause of the failure and learns from it.

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A COMPARISON OF PRESSURIZED AND GRAVITY DISTRIBUTION SYSTEMS FOR WASTEWATER TREATMENT

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ABSTRACT

Pressurized distribution of domestic wastewater over a sand filter surface achieves better treatment than gravity distribution. The pressurized distribution system caused the filter to better remove organics (BOD_5) and suspended solids. Pressurized distribution also caused the sand filter to achieve more complete nitrification than the filter having gravity distribution.

Two slow sand filters 15.2 cm wide, 3.1 m long and 15.2 cm deep were built and loaded with domestic septic tank effluent for 250 days at a rate of 5.1 cm per day. Influent and effluent samples were collected and analyzed for five-day Biochemical Oxygen Demand (BOD_5), suspended solids, ammonia-nitrogen, and nitrate-nitrogen. One filter received septic tank effluent through a 10 cm nominal diameter PVC perforated pipe via a distribution box dosed by a pump with gravity flow from the distribution box to the pipe. The other filter received water through a 2.5 cm nominal diameter PVC pipe having 0.4 cm diameter holes drilled 76.2 cm on center.

The gravity distribution filter system achieved mean effluent values of 36.4 mg/l BOD_5, 19.8 mg/l suspended solids, 37.6 mg/l ammonia-nitrogen, and 46.6 mg/l nitrate-nitrogen. The pressurized distribution system achieved 19.1 mg/l BOD_5, 12.2 mg/l suspended solids, 25.3 mg/l ammonia-nitrogen, and 64.03 mg/l nitrate-nitrogen. Influent to the filters averaged 132.1 mg/l, 90.3 mg/l, 70.3 mg/l, and 3.6 mg/l BOD_5, suspended solids, ammonia-nitrogen, and nitrate-nitrogen, respectively.

INTRODUCTION

Gravity distribution of wastewater over sand filters and into soil absorption trenches is the traditionally accepted method of placing the wastewater on the treatment surface. The work described in this paper shows that improving distribution of the wastewater over the filter surface also improves the quality of treated water.

Gravity distribution for soil absorption trenches generally consists of a distribution box with 10 cm diameter pipe leading to the trenches. The trenches receive septic tank effluent from perforated 10 cm diameter pipe laid at a grade varying from 5 cm per 30.5 m to 10 cm per 30.5 m (Arkansas Department of Health, 1987). The septic tank effluent flows down the perforated pipe and out onto the treatment surface (gravel) through 1 cm diameter holes. With the large pipe and holes and the small flows from the septic tank in the distribution box, most of the effluent flows from only a few holes. Soil absorption trenches may clog due to unequal distribution and overloading a small soil absorption area under the holes receiving flow (Otis, 1985; Mote and Griffis, 1986). The filter used in the gravity distribution system for this study exhibited the flow pattern with most of the septic tank effluent passing through a few holes and heavily loading a small portion of the filter surface.

Gravity distribution of wastewater over buried intermittent sand filters typically uses 10 cm diameter perforated pipe, spaced 0.9 m on center. Unless the pipe is dosed by means of a pump large enough to fill the pipe and cause wastewater to flow from most of the holes, the same heavy loading of an area under a few holes occurs.

Free access or open-top sand filters may be designed with distribution pipes with open ends over a splash plate. A pump forces the wastewater through the pipe to a fitting with the open end pointing toward the splash plate so the wastewater hits the plate and splashes out onto the filter surface (U.S. Environmental Protection Agency, 1980). Of course, this distribution method also heavily loads a small area of the filter around the splash plate unless enough wastewater is pumped onto the filter to cause flooding of the entire surface. Recognizing these problems, designers and researchers began developing better wastewater distribution systems in the late 1970s. About the same time, sewage effluent pumps emerged as a reliable technology with simple, understandable control systems (Carlisle, 1985). Combining effluent pump technology with hydraulic principles led to development of pressurized distribution systems for septic tank-soil absorption systems and sand filters, with North Carolina using the so-called low pressure pipe (LPP) system extensively in the mountainous areas of the state (Cogger, *et al.*, 1982). Meanwhile, Mote *et al.*, 1981; Mote and Pote, 1982 were developing techniques in Arkansas to overcome unequal pressure (and therefore uneven flow) in soil absorption trench distribution systems located on unlevel sites.

The pressurized distribution system for wastewater treatment through sand filters or soil absorption trenches is now commonly recognized as an alternative for overcoming soil and site restrictions that do not allow gravity distribution to function properly (Perkins, 1989; Oregon Department of Environmental Quality, 1988). Pressurized distribution systems are performing well in their function to load the soil or sand treatment surface evenly, spreading the wastewater over a larger area, and preventing failure of the treatment system due to clogging the filter or soil surface. Until recently, however, little information has been available regarding the effectiveness of wastewater treatment due to distributing the wastewater more uniformly over the treatment surface. Certainly no comparison of uniform distribution to "standard" or gravity distribution has been reported.

MATERIALS AND METHODS

Two identical filter trenches were constructed in the laboratory and loaded with domestic septic tank effluent by different distribution techniques. One filter received wastewater by gravity distribution and the other by pressurized distribution.

The filter trenches were 3 m long and 15.2 cm wide built in wooden frames lined with polyethylene. Each filter consisted of 15.2 cm depth of Arkhola Sand and Gravel Company's-28 filter sand with an effective size of approximately 0.25 mm and a uniformity coefficient of ap-

proximately 2.0. The filter sand was underdrained by a 10 cm diameter perforated PVC pipe in 15.2 cm of 1.3 cm pea gravel. The distribution pipe was placed on 5 cm of 1.3 cm pea gravel to protect the sand surface from erosion. Figure 1 illustrates a cross-section of the filters.

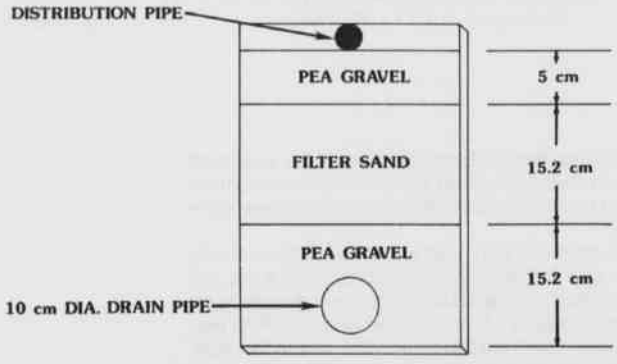

Figure 1. Sand Filter Cross-Section.

The pressurized distribution filter received septic tank effluent pumped from a 113 liter reservoir through a 2.5 cm schedule 40 PVC pipe with 4 mm diameter orifi drilled 76.2 cm on center. The pipe was pressurized at approximately 46 cm of water head by means of a Little Giant Model 1-A pump. The gravity distribution filter received septic tank through 10 cm diameter perforated PVC pipe (ASTM D2729) laid at 10 cm per 30 m or 0.33% slope. The septic tank effluent was pumped from the 113 liter reservoir into a polyethylene distribution box where it flowed down the gravity distribution pipe. Again, a Little Giant Model 1-A pump was used. Both pumps were connected to an electrical control panel having a 96-pin 24-hour timer in series with a DIP switch relay set for 30 seconds. The pumps were simultaneously and automatically operated for 30 seconds 6 times per day at 7.6 liters per minute. The loading rate for each filter was 5.1 cm per day. Samples were taken from the 113 liter reservoir and from each filter underdrain and analyzed for five day Biochemical Oxygen Demand (BOD_5), total suspended solids, ammonia-nitrogen, and nitrate-nitrogen. The filters were operated for 250 days.

The BOD_5 analyses were performed according to Method 5210 B of *Standard Methods,* (1989) 17th Edition, using a YSI dissolved oxygen meter calibrated against the Azide Modification of the Winkler Method (*Standard Methods,* 1989, 4500-0-C). Total suspended solids were analyzed using Method 2540 D of *Standard Methods,* (1989) 17th Edition. The ammonia-nitrogen was analyzed using Method 4500-NH_3C, Direct Nesslerization Method of *Standard Methods,* (1989) 17th Edition. Colorimetric analyses were performed using a Perkin-Elmer Model 554 UV-Visible double-beam spectrophotometer. Nitrate-nitrogen was analyzed using HACH Chemical Company Nitra Ver 5 reagent powder pillows with colorimetric analyses by means of a Perkin-Elmer Model 554 UV-Visible double-beam spectrophotometer (HACH Company, 1989).

RESULTS

The filter receiving septic tank effluent by pressurized distribution consistently treated the wastewater to a higher quality effluent than did the filter receiving septic tank effluent by gravity distribution. Figure 2 shows second-degree polynominals fitted through the BOD_5 data by least squares. Over the 250 day filter runs, the pressurized distribution produced an effluent with an average of 19.1 mg// BOD_5 as compared to an average BOD_5 concentration of 36.5 mg// in the gravity distribution filter. The average BOD_5 in the septic tank effluent was 132.1 mg// . The pressurized distribution reduced the BOD_5 concentration by an average of 85.5 percent while gravity distribution achieved only a 72.5 percent BOD_5 removal.

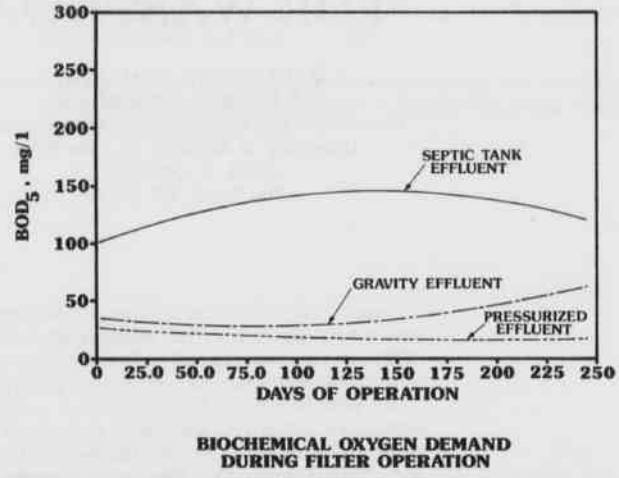

Figure 2. BOD_5 During Filter Operation

The suspended solids data trends are shown in Figure 3 as second-degree polynominals fitted to the data by least squares. Again, the pressurized distribution system consistently produced an effluent with a lower suspended solids concentration than the effluent from the gravity distribution filter. The average pressurized distribution filter effluent suspended solids concentration was 12.2 mg// as compared to 19.8 mg// in the gravity effluent. The suspended solids removal efficiences were 86.5 percent and 78.1 percent for the pressurized distribution and gravity distribution filters, respectively.

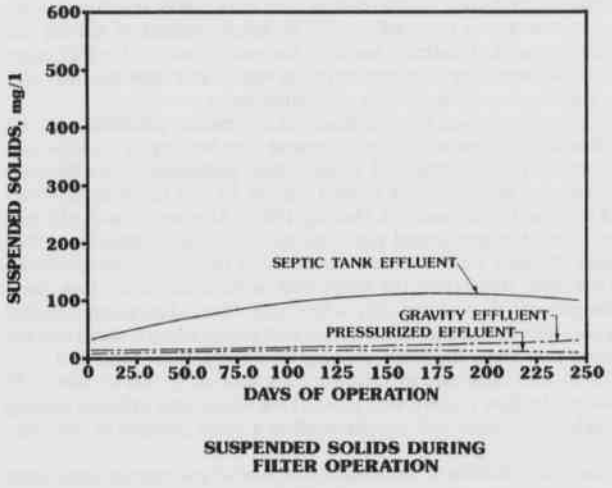

Figure 3. Suspended Solids During Filter Operation.

Figures 4 and 5 show the data for nitrogen conversion in the filters. Although a complete nitrogen balance cannot be computed since total Kjeldahl nitrogen and nitrite nitrogen analyses were not performed, the data still shows the filters' relative performance in terms of nitrification. Again, second-degree polynominals were drawn through the data points by a least-squares fit. The pressurized distribution system consistently produced filter effluent with lower ammonia concentrations and higher nitrate concentrations than in the gravity distribution filter effluent. The ammonia and nitrate concentrations were 25.3 mg// and 64.0 mg// respectively in the effluent from the filter with pressurized

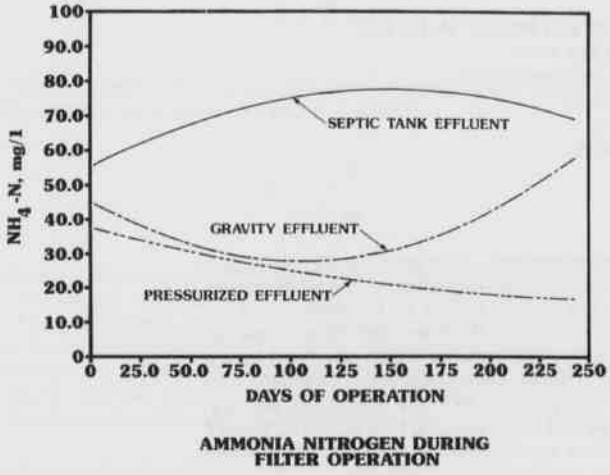

Figure 4. Ammonia Nitrogen During Filter Operation.

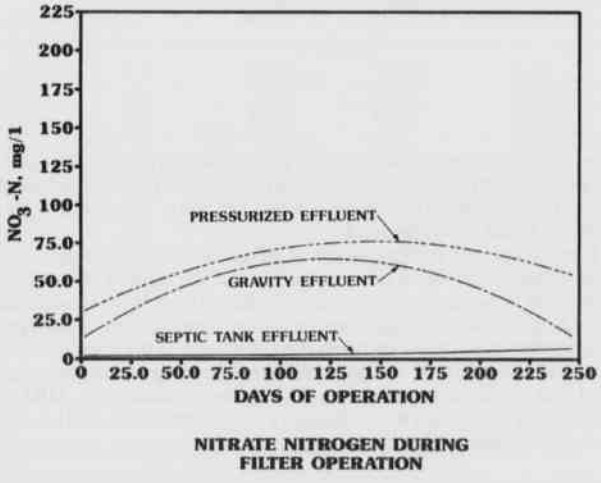

Figure 5. Nitrate Nitrogen During Filter Operation.

distribution. The ammonia and nitrate concentrations in the gravity distribution effluent were 37.6 mg// and 46.6 mg// , respectively. All ammonia and nitrate concentrations are expressed as mg nitrogen per liter.

DISCUSSION

The implications and applications of the data from the filter runs range from better selection of technology for onsite wastewater treatment systems to improving sand filter performance for small municipalities. Shallow soil conditions in North Central Arkansas require that septic tank-soil absorption systems treat the septic tank effluent as efficiently as possible in the soil before infiltrating through fractured rock into groundwater supplies. A different condition, but similar treatment requirement exists in the gravelly soils of Northwest Arkansas, where hydraulic conductivity is high and septic tank effluent moves quickly through the soil into the fractured limestone of the Karst terrain. By recognizing the shallow and high-permeability soils and selecting pressurized distribution of septic tank effluent in the soil absorption system, cost-effective efficient treatment can be achieved. Since "out-of-site out-of-mind" has been the traditional approach to septic system performance, rapid movement of low-quality effluent through the soil and out of sight has been considered desirable. Use of pressurized distribution systems in soil absorption systems treat the septic tank effluent more completely and thereby protect the integrity of the groundwater.

Another application of these data is in the area of sand filters used for small community wastewater treatment systems. These filters may be used to treat centrally-collected septic tank effluent or they may be used to polish facultative lagoon (stabilization pond) effluent. Often, the distribution system for these filters is either gravity distribution through 10 cm diameter pipe or splash plate application. Many small communities struggle to stay in compliance with their permitted effluent discharge limits, and changing from gravity to pressurized distribution may be a cost-effective means to meet their permit limits. In any case, pressurized distribution will cause the sand filters to produce a higher quality effluent.

Currently, work is in progress to evaluate dosing length and frequency and their effects upon filter performance. Preliminary data show that small frequent doses produce a much higher quality effluent than large infrequent doses.

ACKNOWLEDGMENT

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PRINCIPLES AND CLINICAL APPLICATIONS OF MAGNETIC RESONANCE

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ABSTRACT

A review is presented which covers the basic theory of nuclear magnetic resonance (NMR) with regard to angular momentum, magnetic moments, and the classical mechanical description of the NMR experiment. Longitudinal (T_1) and Transverse (T_2) relaxation times are defined as well as the basic pulse sequences used for their measurement. In particular, the 180°-τ-90° and the Hahn Spin Echo pulse sequences are described in detail. Basic Magnetic Resonance Imaging (MRI) theory is discussed with regard to slice selection, frequency encoding, and phase encoding to define the imaged volume element. The equations defining the amount of T_1, T_2, and proton density which contribute to the images are discussed. Common MRI pulsing sequences are described in detail as well as the imaging time equation. Recent in-vivo magnetic resonance studies involving the use of contrast agents, and the use of localized spectroscopy, specifically ^{13}C, ^{19}F, ^{23}Na and ^{39}K, are discussed.

INTRODUCTION

Nuclear magnetic resonance (NMR) imaging of the human body is a relatively new diagnostic technique. It normally is referred to as magnetic resonance imaging or MRI. Figure 1 shows a general block diagram for an MRI system. The patient is placed in a strong magnetic field and radio frequency (RF) pulses are controlled to irradiate a specific volume in MRI. Intensity-modulated images are generated for the body by use of these RF and magnetic fields. Three separate magnetic fields are used. These are the main magnetic field (or the Zeeman field), gradient magnetic fields (G_z,G_x,G_y), and the RF field (or electromagnetic field). The main magnetic field also is known as the static field, $\bar{B}_o$. It is used to align the atomic nuclei and is maintained constant throughout the imaging procedure. The main field strength is typically 1,000 to 15,000 gauss or 0.1 to 1.5 Tesla. The imaging voxel or volume element is defined by the gradient magnetic fields. During the imaging sequence, the gradient fields are rapidly switched for the spatial localization of the resonance. The third electromagnetic field, the RF field, is used to excite the atomic nuclei at their characteristic resonance frequency given by the Larmor equation. The average power of an RF pulse that irradiates the patient is 50 to 500 watts with a duration of between 1 and 10 milliseconds.

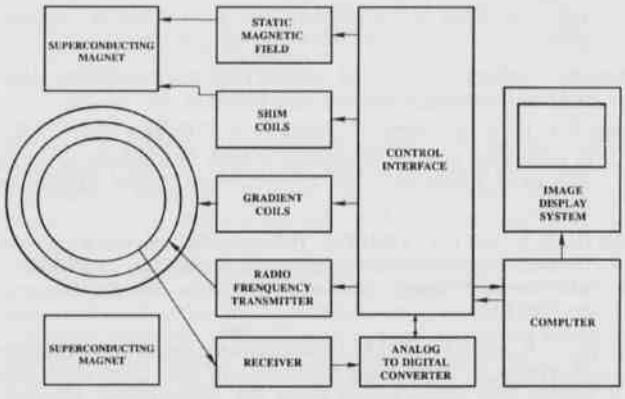

Figure 1. Schematic of a Typical Magnetic Imaging Spectrometer.

In an image, the determination of signal intensities at specific locations is dependent upon proton density and the tissue's chemical environment. The nuclear response from the patient is detected, which upon Fourier transformation and software manipulation is converted into a contrasted image. By using the knowledge of the chemical structure of certain parts of the body, different imaging techniques can be used that change the appearance of the image dramatically. MRI also can be used for in-vivo body chemistry measurements as well as giving anatomical high-quality images.

BASIC THEORY

ANGULAR MOMENTUM

Certain nuclei containing an odd number of protons, when placed in a magnetic field, behave as if they were spinning charged particles. Nuclei that possess this property have associated angular momenta, $\bar{P}$. The maximum observable component of angular momentum is:

$$\bar{P} = \frac{h}{2\pi}\bar{I} = \hbar\bar{I} \qquad (1)$$

where $\bar{I}$ equals the dimensionless angular momentum vector operator and h is Planck's constant.

Nuclei can be classified by their nuclear spin which is also called the nuclear spin quantum number I. Some nuclei, however, possess no angular momenta when their I equals zero. These nuclei with even atomic numbers and even mass numbers (for example, ^{12}C, ^{16}O, and ^{32}S) cannot experience magnetic resonance under any circumstance.

MAGNETIC MOMENT

Each nucleus with $I \neq O$ possesses a magnetic dipole moment or a magnetic moment, $\bar{\mu}$, which is expressed as:

$$\bar{\mu} = \gamma \bar{P} \quad (2)$$

where γ is called the magnetogyric ratio or gyromagnetic ratio; γ is different for different nuclei and is given by:

$$\gamma = \frac{q}{2\ mc} \quad (3)$$

where q is the charge of the nucleus in electrostatic units, m is the mass of the nucleus in grams, and c equals the speed of light in cm sec^{-1}.

The gyromagnetic ratio accounts for nuclear properties not accounted for by the simple picture of a spinning charged particle. $\bar{P}$ is a simple multiple of h as shown in equation (1), but $\bar{\mu}$ and γ are not, and both $\bar{\mu}$ and γ must be determined experimentally for each nucleus. Table 1 lists nuclei of medical interest and their associated gyromagnetic ratios.

Table 1. Nuclear Spin Properties for Some Common Nuclei.

ISOTOPE	I	NMR FREQUENCY IN A 2.3487 TESLA FIELD (MHz.)	NATURAL ABUNDANCE %	RELATIVE SENSITIVITY AT CONSTANT FIELD
^{1}H	1/2	100.00	99.985	1.00
^{2}H	1	15.35	0.015	0.00000145
^{7}Li	3/2	38.86	92.58	0.27123
^{11}B	3/2	32.08	80.42	0.133
^{13}C	1/2	25.14	1.1	0.00018
^{14}N	1	7.22	99.63	0.001
^{15}N	-1/2	10.13	0.37	0.000004
^{17}O	-5/2	13.56	0.037	0.00001
^{19}F	1/2	94.08	100.00	0.833
^{23}Na	3/2	26.45	100.00	0.0925
^{27}Al	5/2	26.06	100.00	0.206
^{29}Si	-1/2	19.86	4.70	0.0037
^{31}P	1/2	40.48	100.00	0.066
^{35}Cl	3/2	9.79	75.53	0.0035
^{119}Sn	-1/2	37.27	7.61	0.0044
^{195}Pt	1/2	21.50	33.80	0.0034
^{199}Hg	1/2	17.83	16.84	0.00019
^{207}Pb	1/2	20.92	22.6	0.002

CLASSICAL MECHANICAL DESCRIPTION OF NMR

Consider the interaction of a magnetic moment, $\bar{\mu}$, with an applied highly homogeneous magnetic field, $\bar{B}_o$, as shown in Fig. 2.

The magnetic interaction between $\bar{B}_o$ and $\bar{\mu}$ generates a torque tending to align $\bar{\mu}$ with $\bar{B}_o$. The magnetic moment, $\bar{\mu}$, does not align with $\bar{B}_o$, but instead $\bar{\mu}$ precesses around $\bar{B}_o$ at an angle Θ. This can be likened to a gyroscope which precesses around the earth's gravitational lines of force.

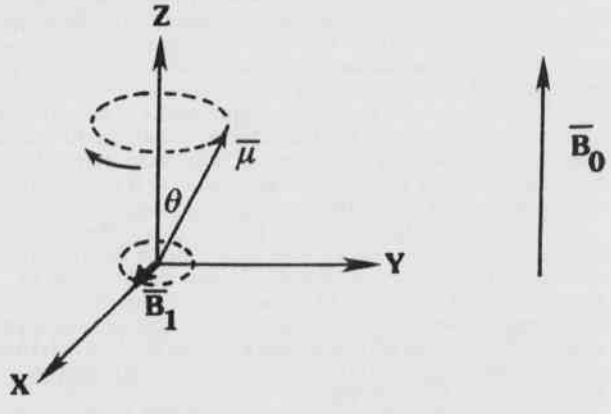

Figure 2. Precession of a Magnetic Moment in a Steady Magnetic Field.

The precessional frequency for nuclei (with $I \neq O$) is given by the Larmor expression:

$$\bar{\omega}_L \text{ (radians } sec^{-1}) = -\gamma \bar{B}_o. \quad (4)$$

Thus, the magnetic moment precesses around $\bar{B}_o$ at the Larmor frequency:

$$\nu_L \text{ (Hertz)} = \frac{|\bar{\omega}_L|}{2\pi} = \frac{\gamma |\bar{B}_o|}{2\pi}. \quad (5)$$

Notice that the angle Θ does not appear and, hence, the nucleus will precess at a frequency governed by its own characteristic gyromagnetic ratio and the magnitude of the magnetic field. Energy, however, is dependent on the angle since classically:

$$E = -\bar{\mu} \cdot \bar{B}_o = -\mu B_o \cos \Theta. \quad (6)$$

We never study a single nuclear amount, $\bar{\mu}$, but rather an ensemble containing a large number of magnetic moments as shown in Fig. 3.

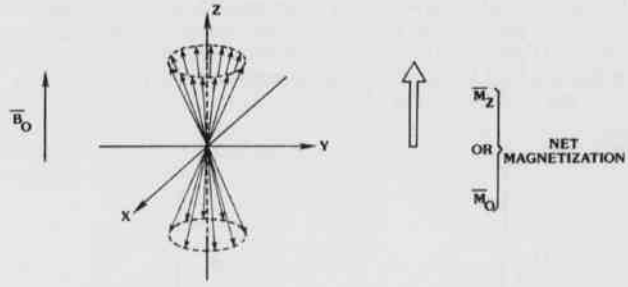

Figure 3. Vector Addition of Magnetic Moments to Form the Macroscopic Magnetization or Net Magnetization for an Ensemble of Identical Magnetic Moments of Nuclei with I = 1/2.

The individual magnetic moments precess around the magnetic field in 2I + 1 possible energy states (Emsley *et al.*, 1965). Thus, for a nucleus with spin 1/2, (for example ^{1}H, ^{13}C, ^{19}F, and ^{31}P) there are two possible energy states. All moments precess at the same frequency, but without phase coherence in the x-y plane. There is a net magnetization $\bar{M}_z$ or $\bar{M}_o$ along the z axis defined by the presence of the magnetic field $\bar{B}_o$, since the Boltzmann distribution slightly favors the lower energy state, that is, aligned along the direction of $\bar{B}_o$.

For nuclei of spin I, the net magnetization is given by (Pake, 1950):

$$\bar{M}_o = \frac{N \gamma^2 \hbar^2 I (I+1)}{3\ k\ T} \bar{B}_o, \quad (7)$$

where k = Boltzmann constant and T = temperature (K).

RF PULSES

In nuclear magnetic resonance experiments, the response of a sample's nuclear magnetization to a time varying external magnetic field $\bar{B}(t) = \bar{B}_o + \bar{B}_1(t)$ is usually investigated. During application of $\bar{B}_1(t)$ at the Larmor frequency, $\bar{B}_o$ becomes vanishingly small and, therefore, the net magnetization $\bar{M}_o$ begins to precess around the direction of the applied RF field, $\bar{B}_1(t)$ (Hahn, 1950). Energy is absorbed from the field $\bar{B}_1(t)$ only when:

$$\nu_{\bar{B}_1(t)} = \nu_L \quad (8)$$

The magnetic vector of the $\bar{B}_1(t)$ field can be thought of as rotating in the x-y plane as shown in Fig. 2. In practice, the rotating field $B_1(t)$ is obtained from a linearly polarized electromagnetic field that results from the passage of electric current at frequency ν through the transmitter coil.

On absorption of energy from $\bar{B}_1(t)$, each individual magnetic moment tips to a different angle Θ, but their precessional frequency remains constant as expressed by the Larmor relation (Slichter, 1963).

In a time t_p(sec), the angle through which $\bar{M}_o$ rotates is given by:

$$\Theta(\text{radians}) = \gamma |\bar{B}_1(t)| t_p \quad (10)$$

Consequently, by controlling the time of the applied RF $\bar{B}_1(t)$ pulse, $\bar{M}_o$ can be rotated clockwise through any angle Θ.

Two RF pulse lengths are used most often in MRI. These are referred to as 90° ($\pi/2$) and 180° (π) pulses (Farrar and Becker, 1971). The equations which describe the behavior of nuclear spin in relation to a fixed coordinate system are very complex. Substantial simplification is achieved if nuclear spin motions are referred to a coordinate system which rotates about the direction of the fixed $\bar{B}_o$ magnetic field with a frequency equal to the frequency of the applied RF field. The coordinate axes in this rotating frame are designated by the use of primes. A pictorial description of the reorientation of $\bar{M}_o$ before and after application of $\bar{B}_1(t)$ for a duration t_p to reorientate $\bar{M}_o$ on either the y′ or -z′ axis is shown in Fig. 4.

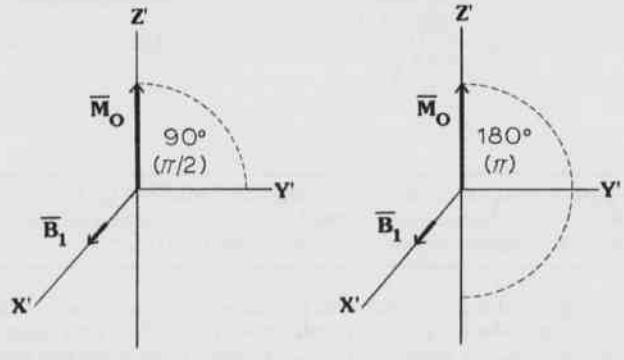

Figure 4. Precession of $\bar{M}_o$ about $\bar{B}_1$ in the Rotating Frame by $\pi/2$ or π radians.

After a pulsed RF field $\bar{B}_1(t)$, an ensemble of N equal spins will relax toward the equilibrium magnetization, given previously by equation 7. Normally, relaxation is described in terms of the time evolution of the parallel and perpendicular components of an instantaneous magnetization $\bar{M}(t)$ (with respect to the Zeeman field $\bar{B}_o$) after $\bar{B}_1(t)$ is removed; time constants, T_1 and T_2, are associated with these parallel and perpendicular components of $\bar{M}(t)$ (Abragam, 1961). In practice, high power RF pulses are used such that $t_p << T_1, T_2$ and, therefore, no significant relaxation occurs during the RF pulses.

DEFINITION OF THE LONGITUDINAL (T_1) AND TRANSVERSE (T_2) RELAXATION TIMES

In an NMR experiment, an RF field $\bar{B}_1(t)$ ($\bar{B}_1(t) << \bar{B}_o$) is applied at the Larmor frequency at right angles to $\bar{B}_o$ as was shown in Figure 2. Application of $\bar{B}_1(t)$ causes spin transitions from the lower to the higher energy state thereby causing the original Boltzmann equilibrium population difference between the lower and upper spin states (Fig. 5a) to decrease. Also, $\bar{B}_1(t)$ causes the individual spins to precess in phase thereby generating a net $\bar{M}_{x,y}$ component of spin in the x-y plane as shown in Figs. 5b and c.

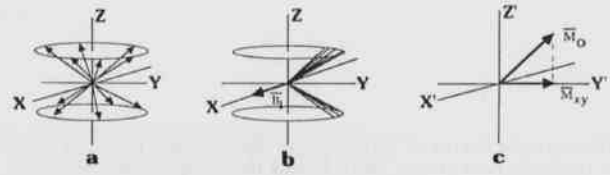

Figure 5. Phase Coherence and Movement of Magnetization Toward the x-y Plane: (a) Nuclei Precessing at Equilibrium, (b) Coherence of Vectors due to Application of $\bar{B}_1$, (c) Net Magnetization and Component in the x-y Plane after Application of $\bar{B}_1$.

After $\bar{B}_1(t)$ is turned off, the imposed phase coherence of the spins immediately begins to decrease due to the presence of local magnetic fields at each nuclear site which add to or subtract from $\bar{B}_o$. Therefore, the spins have a range of precessional frequencies which cause the loss of phase coherence and, thus, any $\bar{M}_{x,y}$ component of spin. Simultaneous spin flips involving two antiparallel spins also can lead to loss of phase coherence. The time scale for loss of the $\bar{M}_{x,y}$ component of spin is associated with a transverse or spin-spin relaxation time constant, T_2.

Reestablishment of the original thermal equilibrium between the spins and the surroundings or the "lattice" also occurs while phase coherence is being lost, and this energy dissipating process is described by a spin-lattice or longitudinal relaxation time constant, T_1. At thermal equilibrium, the spin ensemble has random phase with no $\bar{M}_{x,y}$ component of magnetization; therefore T_1 must by necessity satisfy the condition $T_1 \geq T_2$ (Hawk, 1973).

FREE INDUCTION DECAY

Suppose a 90° pulse is applied along the x′ axis in the frame rotating at the RF frequency. Following the pulse, $\bar{M}_{x,y}$ lies entirely along the y′ axis, as indicated in Fig. 5c. Since the probe assembly is arranged to detect signals induced in a receiver coil along the fixed x or y axis, the magnitude of $\bar{M}_{x,y}$ determines the strength of the observed signal (called a free induction decay [FID] signal). As transverse relaxation occurs, the signal decays. In a perfectly homogeneous field, the time constant of the decay would be T_2, however, the free induction decay signal actually decays in a time T_2^* that is determined primarily by B_o inhomogeneity. This is a consequence of the fact that nuclei in different parts of the field precess at slightly different frequencies, and therefore, phase coherence is lost.

Figure 6a shows the pure exponential decay that results from an RF pulse applied exactly at the resonance frequency of a single type of nucleus. This decay directly measures the decrease in $\bar{M}_{x,y}$ since the usual experimental arrangement provides a detector which is phase referenced to the RF transmitter (Farrar and Becker, 1971). Thus, even though detection of the signal occurs when no RF is directly applied to the nuclear spin system (that is, after the pulse), the RF reference is applied to the detector continuously. The detector responds to the magnetization which has a fixed phase relation to $\bar{B}_1(t)$, which occurs along a fixed axis in the rotating frame (in this case the positive y′ axis).

Suppose now that the transmitter RF is slightly different from the Larmor frequency of the nuclei. If we again consider the frame rotating at the radio frequency, then immediately after the 90° pulse, $\bar{M}_{x,y}$ lies along the y′ axis. However, $\bar{M}_{x,y}$ now rotates relative to the rotating frame, and the detector displays not only the exponentially decaying value of $\bar{M}_{x,y}$, but also the interference effects as $\bar{M}_{x,y}$ and the reference frequency alternately come in and out of phase with each other. A typical FID response is shown in Fig. 6b.

Measurement of the free induction decay is how the magnitude and other characteristics of $\bar{M}_o$ are determined. The four components of an FID are shown in Fig. 7. The FID following a 90° pulse provides

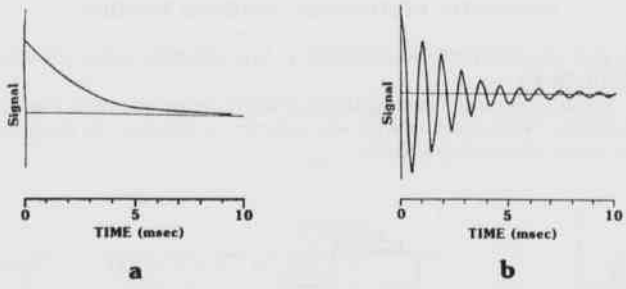

Figure 6. (a) Free Induction Decay (FID) for RF Precisely at the Larmor Frequency (b) FID for RF off Resonance.

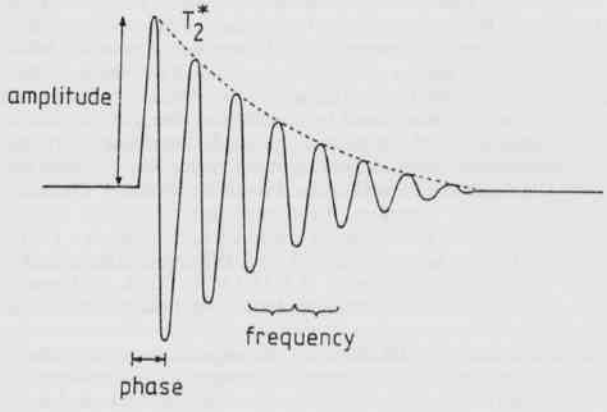

Figure 7. The Informational Content of an FID.

the spectral information required in Fourier transform NMR, and the FID resulting from sequences of two or more pulses is used in the determination of T_1 and T_2 relaxation times. Proton density (ρ) is determined from the initial amplitude which is proportional to the number of hydrogen nuclei.

In Fig. 8, $\overline{M}_z$ and $\overline{M}_{x,y}$ are plotted as a function of time. The equations for the two curves are:

$$\overline{M}_z = \overline{M}_0 [1 - e^{-t/T_1}] \quad (11)$$

$$\overline{M}_{x,y} = \overline{M}_0 e^{-t/T_1} . \quad (12)$$

MRI images of tissues are generated from the T_1, T_2, and hydrogen nuclei density measurements. The chemical structure determines the contrast.

RELAXATION TIME CONSTANT MEASUREMENTS

180°-τ-90° SEQUENCE FOR THE MEASUREMENT OF T_1

The longitudinal relaxation time, T_1, is often measured by the 180°-τ-90° sequence where an initial 180° pulse directed along the x′ axis rotates the equilibrium magnetization clockwise from the $+z'$ to

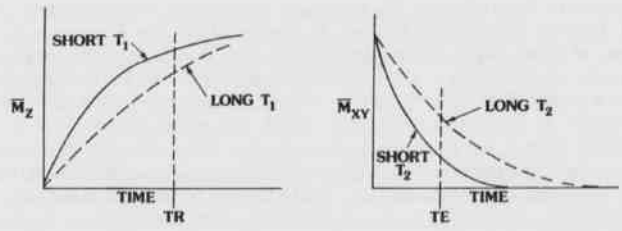

Figure 8. Recovery for $\overline{M}_z$ with Short and Long T_1 Values and Loss of Phase Coherence ($\overline{M}_{xy}$) in the x-y Plane for Short and Long T_2 Values.

the $-x'$ axis. After a variable time τ, during which nuclear relaxation occurs, a 90° pulse directed along the x′ axis rotates the magnetization clockwise 90°. Whether the magnetization is rotated to the $+y'$ or the $-y'$ axis depends on the time interval τ relative to the value of T_1. If $\tau << T_1$, the magnetization which was rotated to the $-z'$ axis by the first 180° pulse will have just begun its exponential recovery toward reestablishment of the equilibrium magnetization. Therefore, the magnetization will lie along the $-z'$ axis and the 90° pulse will rotate this magnetization clockwise to the $-y'$ axis. The signal is nulled when the time interval $\tau = .69T_1$ since the magnetization passes through the origin.

If $\tau > .69T_1$, the magnetization will lie along the $+z'$ axis and the 90° pulse will align the magnetization along the $+y'$ direction. Thus, a plot of the sampled magnetization versus τ will yield the exponential plot shown in Fig. 9; each dot corresponds to a separate 180°-τ-90° sequence.

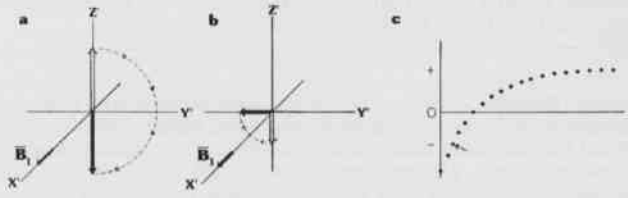

Figure 9. Determination of T_1 by the 180°-τ-90° Sequence. (a) $\overline{M}_0$ inverted at time 0 by a π pulse, (b) $\overline{M}$ rotated by a $\pi/2$ pulse after a time τ, (c) The initial amplitude of the free induction decay is plotted as a function of τ. Each point corresponds to a separate 180°-τ-90° sequence. The point corresponding to (b) is indicated by the arrow.

A decided drawback of the 180°-τ-90° sequence is its relative inefficiency since a full $5T_1$ time interval should be allowed to reestablish the equilibrium magnetization before initiation of the next sampling sequence. Also, only one point is measured on the exponential curve for each 180°-τ-90° pulse sequence (Hawk, 1973).

MEASUREMENT OF T_2 BY THE SPIN-ECHO METHOD

The contribution of inhomogeneity in $\overline{B}_0$ precludes the use of the decay time, T_2^* as a measure of T_2. An ingenious method for overcoming the inhomogeneity problem was first proposed by Hahn (1950), who called it the spin-echo method. The method consists of the application of a 90°-τ-180° sequence and the observation at a time 2τ of a free induction "echo" (Farrar and Becker, 1971). The method is shown in Fig. 10 which depicts the behavior of the magnetization in the rotating

frame. In Figure 10 (a), $\overline{M}_o$ is rotated through 90° by application of $\overline{B}_1(t)$ along the positive x′ axis. In Figure 10 (b), the $\bar{\mu}_i$ begin to fan out, as some nuclei precess faster and some slower than the rotating frame which rotates at the reference frequency of the RF transmitter. At a time τ after the 90° pulse, a 180° pulse is applied, also along the positive x′ axis, as shown in Fig. 10 (c). The effect of this pulse is to rotate each $\bar{\mu}_i$ by 180° about the x′ axis. Thus, those $\bar{\mu}_i$ that were moving faster than the frame (shown in [b] moving toward the observer or clockwise looking down the z′ axis) naturally continue to move faster, but in Fig. 10 (d) their motion is now away from the observer. At time 2τ, all $\bar{\mu}_i$ come into phase along the negative y′ axis as shown in Figure 10 (e). The continuing movement of the $\bar{\mu}_i$ causes them again to lose phase coherence in Fig. 10 (f).

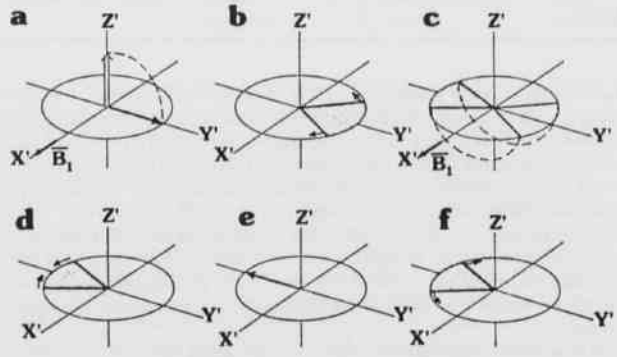

Figure 10. The Hahn Spin-Echo Experiment. (a) $\overline{M}_o$ is rotated through 90° by application of $\overline{B}_1$, (b) the $\bar{\mu}_i$ begins to fan out, (c) application of a 180° pulse at a time τ rotates all $\bar{\mu}_i$ about the x axis, (d) The $\bar{\mu}_i$ continue their relative motion with respect to the rotating frame frequency, (e) At a time 2τ all $\bar{\mu}_i$ refocus along the $-y$ axis creating an echo, and (f) The $\bar{\mu}_i$ begin to dephase after the time 2τ.

The rephasing of the $\bar{\mu}_i$ causes a free induction signal to build to a maximum at 2τ, but the signal is, of course, negative relative to the initial free induction decay since rephasing of the $\bar{\mu}_i$ occurs along the negative y′ axis. If transverse relaxation did not occur, the echo amplitude would be as large as the initial value of the signal following the 90° pulse. However, each $\bar{\mu}_i$ decreases in magnitude during the time 2τ because of the natural processes responsible for transverse relaxation. Thus, the echo amplitude depends on T_2, and this quantity may in principle be determined from a plot of peak echo amplitude as a function of τ. As in the measurement of T_1, it is necessary to carry out a separate pulse sequence for each value of τ and to wait between pulse sequences as adequate time (at least five times T_1) for restoration of equilibrium. A typical set of data from a multiple spin-echo experiment is shown in Fig. 11.

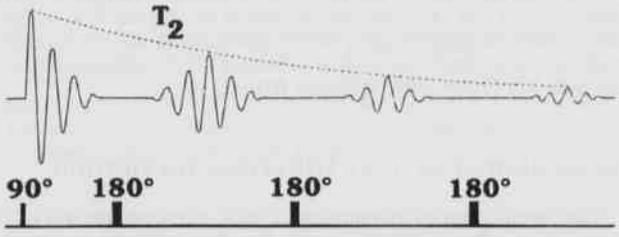

Figure 11. A Typical Carr-Purcell Experiment. Connection of the Peak Amplitudes of Each Successive Spin-Echo Defines the "True" T_2 Relaxation Time.

MAGNETIC RESONANCE IMAGING THEORY

SLICE SELECTION, FREQUENCY ENCODING, AND PHASE ENCODING

In transverse slice imaging, the coordinate system shown in Fig. 12 is chosen. The z direction is the slice selection, x direction the frequency, and y direction the phase.

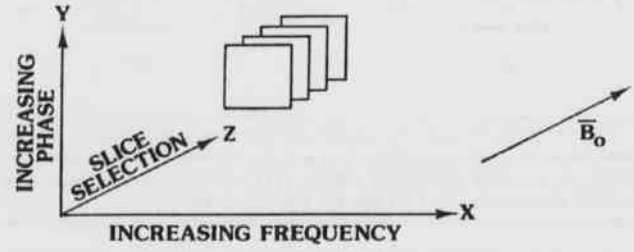

Figure 12. The Coordinate System for an MRI Experiment.

Firstly, the z gradient (G_z) is turned on to select the plane or slice to be imaged. When the z gradient is on, the field strength at one end of the magnet bore is stronger than at the other. Therefore, when a 90° pulse is turned on at a specific frequency, only protons in a specific slice (which satisfy the Larmor equation) are excited. The thickness of the selected slice is determined by the slope of the gradient field and the frequency width of the RF pulse which is controlled by the pulse power and pulse duration. According to RF theory, the frequency range spanned by a pulse of RF is equal to: Frequency Range = Transmitter Frequency $\pm$ $1/t_p$. Therefore, if the transmitter frequency were 42.6 MHz (corresponding to the Larmor frequency for protons in a 1.0 Tesla field) and if the t_p selected were 10 μsec, the actual transmitted frequency would cover the range of 42.5-42.7 MHz. Thus, the longer the pulse, the narrower the slice that can be selected since the RF frequency spread is reduced.

At the termination of the 90° pulse, all magnetic moments in the slice are precessing in phase at the same frequency and, thus, no spatial information can be obtained. Spatial locations can be obtained, however, by frequency and phase encoding of the precessing nuclei. Phase can be encoded in the y direction by turning off the slice-selection gradient, G_z, and turning on the phase-encoding gradient, G_y. While the phase-encoding gradient is on, the processional frequencies will increase linearly in the y direction in proportion to the applied gradient field strength. When this gradient is turned off, the precessional frequencies will be the same again; however, the phase angles will be different along the y direction (that is, the phase has been encoded). For readout, the slice-selection gradient (G_z) is again turned on, the 180° RF pulse is triggered, the slice-selection gradient is turned off, and the frequency-encoding gradient (G_x) is turned on during echo reception. The gradient in the x direction increases the frequencies of the received echoes lineraly in the x direction so that spatial information can be obtained in the x direction (that is, the frequency is encoded). The received echo consists of a series of frequencies of specific amplitude and phase where frequency determines the x coordinate, phase determines the y coordinate, and amplitude determines the signal intensity. All information is retrieved from the echo by applying the Fourier transform. In practice, because of the high resonant frequencies associated with the technique, a single phase-encoding step is performed for each y coordinate. Typically 128, 192, or 256 phase encoding steps are used to obtain a single column in one slice. Thus, the Single Slice-Single Echo pulsing sequence shown in Fig. 13, would be repeated 128, 192, or 256 times although only two are shown. Frequency is typically encoded in 256 increments, yielding array sizes of 256 X 128, 256 X 192, or 256 X 256 pixels.

For imaging the sagittal plane, the x gradient would be used for plane selection, and for imaging the coronal plane the y gradient would be used. The frequency and phase would be encoded by the other two gradients.

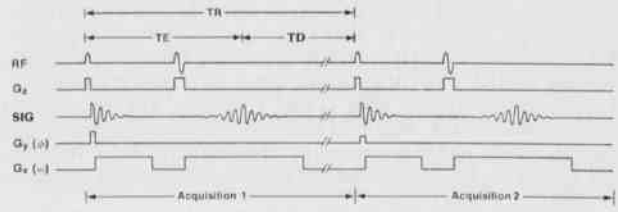

Figure 13. The Spin-Echo Sequence.

When the spin echo technique is used, the MRI signal intensity is given by:

$$SI = DF\,[1 - e^{-TD/T_1}]e^{-TE/T_2}$$

where D is a function of proton density and F is a flow factor (Bushong, 1988) and TD and TE are defined in Fig. 13.

In the data collection process, by defining TR, TE, and TD, the amount of T_1 and T_2 contributed to the images can be controlled. An example is where TE with respect to T_2 is shortened which reduces T_2 effects because e^{-TE/T_2} approaches 1. The T_1 effects can be reduced by making TD long with respect to T_1, because then e^{-TD/T_1} approaches 0. If both of these effects are reduced, then an image can be obtained that emphasizes the effects of proton density. To obtain an image that illustrates both T_2 and proton density, the T_2 contribution must be increased by lengthening TE while TD remains long. To increase the contribution of T_1 and obtain an image illustrating T_1 and proton density effects, TD would be shortened while TE remains short.

SINGLE SLICE-MULTIECHO METHOD

By increasing TE, the echo time, the T_2 effects are increased. Simultaneous echoes (which increase T_2 weighting) can be obtained by multiple echo times. The pulsing sequence for performing spin echo, single transverse-slice, multiecho imaging is shown in Figure 14. Each echo is diminished in amplitude as shown in Fig. 11. The TE increases with each additional 180° pulse, therefore, increasing the T_2 effects. The phase and frequency information is contained in each echo, which is necessary for the generation of a single line for each image. The phase encoding and frequency encoding gradients are the same as those for the Single Slice-Single Echo sequence shown in Fig. 13.

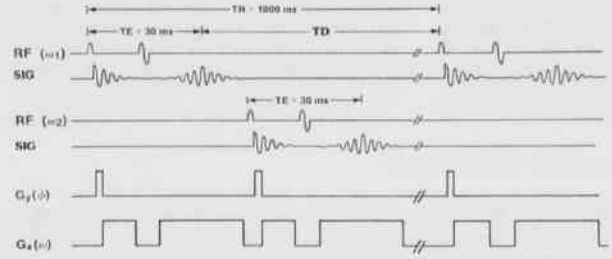

Figure 14. The RF Pulse Sequences Necessary for Multislice Spin Echo Imaging.

MULTISLICE-SINGLE ECHO

Another method is the multislice-single echo method shown in Fig. 14. In multislice imaging, TD, the recovery time, is used after the acquisition of the first slice to collect data from other slices. At each slice, one line at a time is used to collect data. The recovery time determines how many slices can be obtained. In order to prevent any overlap of adjacent slices, a small space is left between selected slices.

MULTISLICE-MULTIECHO

We can obtain multiple echo images from multiple slices by merging the multiecho sequence with the multislice sequence. The pulsing sequence for this multislice, multiecho imaging is shown in Fig. 15. Here, as in the a multislice-spin echo method, the recovery time from the first slice after the last echo is used to collect echoes from additional slices (Bushong, 1988).

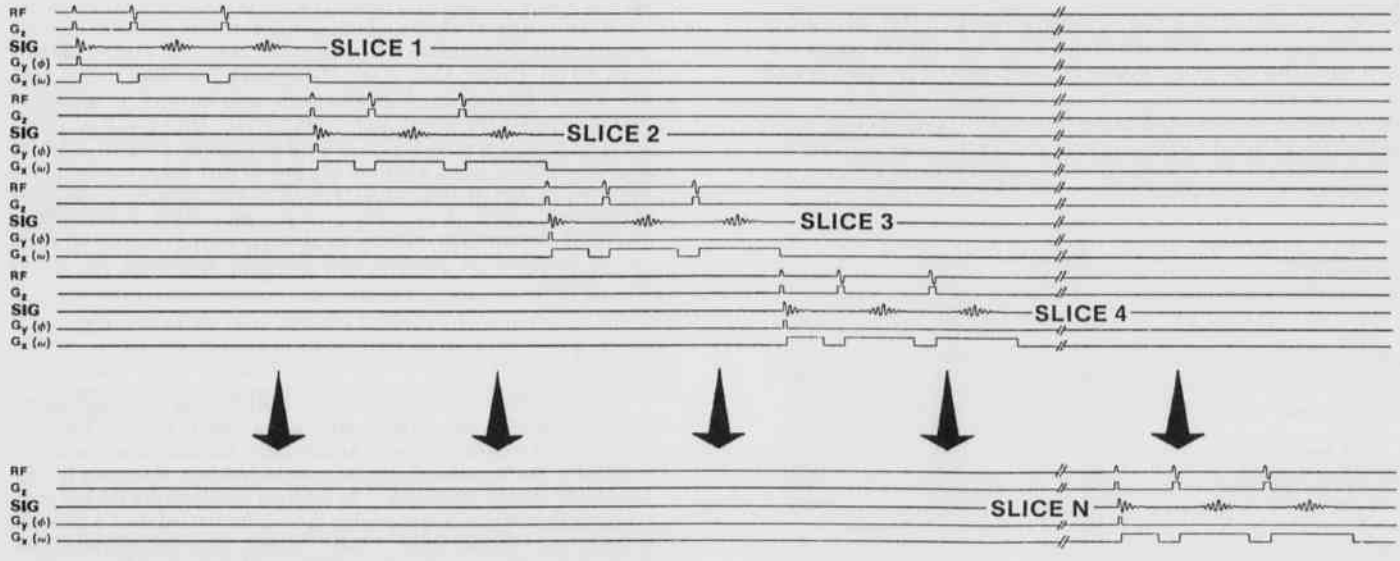

Figure 15. Multislice, Multiecho Spin Echo Imaging.

THREE DIMENSIONAL FOURIER TRANSFORM

Instead of multislice imaging, true volume imaging can be performed by using three-dimensional Fourier transform (3DFT). The z gradient in this technique is used to encode frequency in the z direction. The phase is encoded separately in the x and y directions by the use of the x and y gradients. The complex frequency distribution that is obtained is decoded by 3DFT and utilized to generate images of slices in any projection. There is an isotropic volume collection if the step size of the z gradient is the same as the x and y gradients; it is anisoptropic otherwise.

IMAGING TIME IN MRI

In order to generate high quality images, one pulse sequence and data collection process for each line are not sufficient for a good image. Therefore, it is necesary to utilize repetitive pulse sequences to collect multiple data sets from a single line and average before image reconstruction. The following equation is used to calculate the imaging time:

$$\text{Time} = N_y \times n \times TR, \qquad (13)$$

where N_y = the number of gradient steps in the y or phase-encoding direction, n = the number of signals averaged into one line, and TR = the sequence repetition time.

The time to acquire images is one of the primary problems of MRI. Two to 20 minutes are common imaging times. Again, if we look at equation 13, we see that by reducing TR we can significantly reduce the imaging time. This can be done by using tip angles, which are less than 90°. This would result in nuclei returning to equilibrium in significantly less time, allowing smaller TR's. However, a gradient reversal or gradient echo technique also would have to be used instead of the 180° rephasing pulse.

IN-VIVO MAGNETIC RESONANCE STUDIES

CONTRAST AGENTS

In-vivo NMR images are dependent upon proton density, T_1, T_2, and flow characteristics. Both relaxation times reveal a significant difference between normal and abnormal tissue (see Table 2). A prediction by some earlier workers was that a knowledge of the first three parameters (for a particular tissue) would enable a successful non-invasive tissue biopsy. However, with greater clinical use of MRI, the difficulty in separating lesions, such as neoplasms or abscesses, of the central nervous system from surrounding cerebral edema became apparent. Several investigators suggested the use of contrast agents as used with CT-scan, to enhance the usefulness of MRI (Bydder *et al.*, 1982; Alfidi *et al.*, 1982). Gadopentetic acid (Gd-DTPA) is the most commonly used contrast agent in MRI. This paramagnetic metal ion chelate enhances proton relaxation, shortening both T_1 and T_2 in-vivo. The definition of renal functional status, improved definition of normal anatomy and pathologic lesions, and improvement in the definition of lesion vascularity are among the benefits of contrast enhancement in MRI (Runge *et al.*, 1983).

Table 2. Relative Spin Density and Approximate T_1 and T_2 Relaxation Times at a Field Strength of 1.0 Tesla for Various Tissues.

TISSUE	RELATIVE SPIN DENSITY	T_1 (ms)	T_2 (ms)
Fat	98	180	90
Liver	91	270	50
Renal cortex		360	70
White matter	100	390	90
Spleen	92	480	80
Gray matter	94	520	100
Muscle	100	600	40
Renal medulla		680	140
Blood	90	800	180
Cerebrospinal fluid	96	2000	300
Water		2500	2500
Air	<1		
Lung	1-5		
Cortical bone	1-10		
Kidney	95		
Pancreas	86		

LOCALIZED SPECTROSCOPY

In addition to its diagnostic usefulness as a non-invasive in-vivo imaging tool, use of NMR spectroscopy to monitor in-vivo metabolites and physiologically important ions in organs and tissues provides an unparalleled opportunity for new venues in medical research. A combination of in-vivo proton imaging and localized spectroscopy on a particular metal ion (such as ^{23}Na, ^{31}P, or ^{39}K) can give the physiological state of the tissue in the localized region. For example, the ^{31}P spectrum from muscle or brain tissue contains signals from adenosine triphosphate (ATP), inorganic phosphate, creatine phosphate, and sugar phosphates which can be used to calculate the concentrations of each of these components in the tissue. Intracellular pH of the tissue can be calculated from the position of ^{31}P signal from inorganic phosphate (Hoult *et al.*, 1974; Dawson *et al.*, 1977; and Chance *et al.*, 1980). A combination of ^{31}P and ^{1}H NMR spectroscopy allows the study of the phosphorylated metabolites by ^{31}P NMR and determination of intracellular lactate levels by ^{1}H NMR (Bekar *et al.*, 1985).

^{13}C MRI

Since the natural abundance of ^{13}C is only 1.1%, only compounds such as triacylglycerols or glycogen, which can have very high intracellular concentrations, are detectable at the natural abundance level by ^{13}C NMR. However, this low natural abundance has been used to advantage for metabolic studies by following the flow of ^{13}C label introduced by specifically labelled substrates (Cohen, 1983; Reo *et al.*, 1984; Shulman *et al.*, 1979). Ackerman and co-workers (Reo *et al.*, 1984) have used this technique by giving ^{13}C enriched glucose intravenously to fasted rats to follow the kinetics of glycogenesis from glucose and subsequent glycogenolysis in-vivo under a number of conditions. This was done by using a surface coil which was placed on a surgically exposed liver. They also studied the effects of hormonal treatment on hepatic glucose metabolism in-vivo by ^{13}C NMR. Natural abundance ^{13}C NMR spectra of human muscle samples, before and after removal of neutral fat by extraction with isopentane, have been used by Baramy *et al.* (1984). Earlier Alger *et al.*, (1981) ran a feasibility study to obtain natural abundance ^{13}C NMR species coupled with ^{1}H spectra of muscle in-vivo in the human arm. More recently, Starewicz *et al.* (1985) acquired natural abundance ^{13}C spectra of a human subject. All spectra were obtained using a surface coil placed over the liver, chest, and the head. No spatial localization techniques were used when obtaining the spectra. Clearly, it is evident that the application of whole body ^{13}C NMR spectroscopy without surgical exposure is dependent upon the development of sensitive and practical techniques for spatial localization.

^{19}F MRI

^{19}F is a relatively attractive nucleus for MRI imaging and spectroscopy since it has a 100% natural abundance and a relative sensitivity of 0.83 (compared to 1.00 for protons). Additionally, minimal adjustments are required in the instrumentation because its resonant frequency is very close to the proton frequency. The inherent problems are the low concentrations at which it is available in-vivo (estimated as 2.6 gms for a 70Kg man) (Thomas *et al.*, 1982). The soft tissue concentration will be much less since most fluorine is incorporated in bone (fluorapetite). The potential for ^{19}F NMR imaging using fluorodeoxyglucose (FDG) has been reviewed by Thomas *et al.* (1985) who showed that 3-FDG

holds considerable promise for NMR applications in the study of glucose metabolism. Nunnally *et al.* (1985) studied the uptake and metabolism of fluorinated anti-tumor agents such as 5-fluorouracil with ^{19}F spectroscopy in intact rabbits. They postulated the nearly simultaneous observation of ^{19}F and phosphorus metabolism by ^{31}P utilizing a doubly tuned coil which represents a significant application of in-vivo NMR in the evaluation of tumor therapy.

The extremely low endogeneous concentration of mobile fluorine coupled with high NMR sensitivity and 100% natural abundance makes ^{19}F very suitable for use in in-vivo studies which involve the use of biocompatible fluorine tracer compounds.

^{23}Na AND ^{39}K MRI

The cellular compositions of sodium and potassium and their concentration gradients across the cellular membrane play a vital role in various physiological processes. Excess accumulation of sodium ions in the cells is known to be the cause for certain cancers, diabetes, and hypertension (Camerson *et al.*, 1980; Boynton *et al.*, 1982; Moore *et al.*, 1983; Blaustein, 1977). Sodium magnetic resonance has the potential of contributing physiological and clinical information which is unavailable from either proton or phosphorus NMR studies. Applications include the study of tumor processes, normal cardiac or renal physiology, and electrophysiological events such as the alterations of the intracellular Na^+ and/or Na^+/K^+ ATPase activity due to pharmacological intervention or pathological events. The recent advent of lanthanide shift reagents has enabled separation of the extracellular sodium signal from that of the intracellular signal (Gupta and Gupta, 1982; Pike *et al.*, 1984). Since the overall sensitivity of ^{23}Na is near that of ^{1}H nucleus, it has been used for generating images (Hilal *et al.*, 1985; Ra *et al.*, 1986; Turski *et al.*, 1987; Burstein and Mattingly, 1989), even though the images do not provide the same quality of anatomic detail obtained with proton NMR.

It was observed by Cope (1965, 1967) that the concentrations of sodium in biological tissue as determined by ^{23}Na NMR was 60% smaller when compared to other chemical techniques. This leads to the famous NMR 'visibility' question. Sodium and potassium are quadrupolar nuclei and they exhibit NMR 'invisibility' since two of the outer transitions for a quadrupolar nucleus, that is, $-3/2 \rightarrow -1/2$ and $1/2 \rightarrow 3/2$, have a different resonance frequency and a very short relaxation time, which broadens the signal obtained at these frequencies. Thus, only the central transition ($-1/2 \rightarrow 1/2$) is observed which comprises 40% of the total signal intensity (Hubbard, 1970; Bull, 1982). We have studied the visibility of ^{7}Li in biological tissue extensively in our laboratory and find that ^{7}Li visibility decreases by 10-15% going from 40 mm ^{7}Li to 1 mm ^{7}Li in red blood cells (Gullapalli *et al.*, 1990).

The use of shift reagents for in-vivo studies is being actively pursued and rat studies which correlated the accumulation of intracellular sodium with the deletion of high energy phosphorus metabolites indicated that the rate of sodium accumulation increased with the depletion of ATP (Blum *et al.*, 1986; Balschi *et al.*, 1986). Except for imaging, no other studies have been done on humans. With the advancements in instrumentation, non-toxic shift reagents, and better spatial localization techniques, ^{23}Na NMR techniques will be applied to study various physiological processes in the very near future.

The major disadvantage of ^{39}K NMR is its poor sensitivity. Some work is being done to study the transport kinetics of ^{39}K by using ^{87}Rb as a sensitive probe (improves the sensitivity by a factor of 19) (Allis *et al.*, 1989). No studies on humans have yet been performed. Research continues in the enhancement of the ^{39}K signal and other new techniques that may eliminate the use of shift reagents which may alter the biological activity.

CONCLUSION

Over the years, the application of MRI imaging and spectroscopy in-vivo has broadened the horizons for different nuclei. This has enabled the scientist to innovate new pulse sequences, improve sensitivity through better instrumentation, and better in-vivo localization techniques. There is always a need to reduce the scan time on a patient for diagnostic purposes. The advances in research have enabled researchers to better understand and characterize flow phenomena, especially blood flow in the vasculature. The emphasis is also in the direction of higher fields for imaging purposes. The current FDA regulations permit the use of up to 1.5 Tesla magnets for in-vivo imaging purposes. Research on small animals is being done at fields as high as 9.0 Tesla. Four Tesla magnets are being used for in-vivo human research at a few locations in the US. Generally, higher fields would enable one to obtain better spectroscopy results rather than just improved images. A combination of imaging and localized spectroscopy (as an indicator for metabolic character of tissue in-vivo) appears to be the direction for magnetic resonance in medicine.

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A COMPARISON OF METHODS FOR PURIFICATION OF DNA FROM RICE

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ABSTRACT

Three techniques were employed to purify genomic DNA from deomstic rice (*Oryza sativa* L.). Following extraction, the DNA was electrophoresed through agarose to determine its integrity. We determined that spooling yielded better quality, through lower quantity DNA than either of the other two techniques.

INTRODUCTION

Rice (*Oryza sativa* L.), a major cereal grain crop in world food production, is a dietary staple in many third world countries. Arkansas supplies 60% of the nation's rice for exportation, thus higher yields from genetically engineered rice would not only benefit third world countries, but would also economically benefit the United States and subsequently Arkansas.

Rice has been difficult to engineer genetically due to the barriers related to *Agrobacterium*-mediated transfer in many monocot species. Rice tissue culture techniques have proven quite effective, although other gene transfer systems need to be explored (Dekeyser *et al.*, 1989). One of the first steps in genetically engineering rice is developing a method for purification of genomic DNA.

In this study, we extracted DNA from the major rice cultivars (Huey, *et al.*, 1987) in production in Arkansas (Newbonnet, Lemont, and Tebonnet). The DNA was further purified by ethanol (Et-OH) precipitation, spooling, or cetyl-trimethyl-ammonium bromide (CTAB) extraction and the methods were compared. The DNA obtained was quantified using diamino-phenyl-indole (DAPI) and electrophoreses through agarose to determine the degree of shearing. From the results, we were able to determine which extraction/purification method is most effective for obtaining rice genomic DNA.

MATERIALS AND METHODS

We obtained 3 rice cultivars, Newbonnet, Lemont, and Tebonnet, from the University of Arkansas Rice Research and Extension Center in Stuttgart, Arkansas. Each cultivar was grown in laboratory flats under artifical lighting until the leaves were approximately 13 cm long. Two grams of leaf material were harvested for each analysis. The leaf was finely chopped and pulverized in liquid nitrogen. While still frozen, the tissue was transferred to a 50 ml Falcon tube. To the tube, 15 ml of extraction buffer (10 mM Tris, 50 Mm EDTA, 500 Mm sodium chloride, and 1 Mm beta-mercaptoethanol) and 1 ml of 20% lauryl sulfate (SDS) were added. After a 10 minute incubation at 43 °C, 10 units (100 ul) of Proteinase-K were added to the tube, and the tube was allowed to incubate overnight at 43 °C.

The next day, following addition of 5.0 ml of 5 M potassium acetate, the tube was incubated at 0 °C for 20 minutes. After the incubation period, the sample was centrifuged at 10,000 g for 30 minutes. The supernatant was decanted through Miracloth into a Corex tube containing 10 ml of cold isopropyl alcohol. The tube was gently shaken, and then incubated at −20 °C for 20 minutes. Following extraction of the DNA, 3 different purification methods were used.

SPECIFIC PURIFICATION METHODS

For the Et-OH precipitation method, the sample was centrifuged at 10,000 g for 30 minutes. The pelleted DNA was allowed to dry. The pellet was redissolved in 1 ml of TE (10 mM Tris, 1 mM EDTA, pH 7.5). The DNA was microfuged for 10 minutes to remove any insoluble debris. The sample was divided between 2 microfuge tubes and 50 ul of 3 M sodium acetate and 1 ml of ethanol were added to each tube. The tubes were then shaken well, and the DNA was pelleted for 5 minutes in the microfuge. The pellet was rinsed with 70% ethanol before the tube was microfuged for another 5 minutes. The DNA pellet was allowed to dry and resuspended in 100 ul of TE and stored at room temperature.

The second method was the spooling technique. A glass hook was prepared using a disposable Pasteur pipette. Each DNA sample was removed from the Corex tube by twirling in onto the glass hook. The DNA was rinsed in cold 100% ethanol, dried and redissolved in 100 uL of TE.

In the CTAB procedure, the DNA was centrifuged at 10,000 g for 20 minutes, and the DNA pellet was dried. The dry pellet was resuspended in 0.5 ml of TE. The DNA was centrifuged for 10 minutes to remove any debris, and 50 ul of 3 M sodium acetate and 100 ul of 1% CTAB were added. The DNA was incubated at 50 °C for 15 minutes, then extracted in an equal volume of phenol-chloroform-isoamyl alcohol (24:24:1). After centrifuging, the upper layer was recovered, and re-extracted with chloroform-isoamyl alcohol (24:1). The DNA was precipitated by adding twice the volume of cold 100% ethanol, and microfuged for 5 minutes. The DNA pellet was washed with 70% ethanol, dried, and resuspended in 100 ul of TE.

The concentration of DNA in each sample was determined by comparing a 2X serial dilution of rice DNA to known concentrations of salmon sperm DNA in 1% DAPI. To determine the degree of damage to the rice DNA, a 5 ul sample was electrophoresed on a 1% agarose gel in Tris-Borate-EDTA at pH 8.8 (Maniatis, *et al.*, 1982) using .75 volts/cm of agarose for 3 hours.

STATISTICAL METHODS

The experimental design used 3 purification methods for each of the 3 cultivars of rice. This produced a 3 X 3 factorial Analysis of Variance (Steele and Torrie, 1960). The design was replicated twice.

RESULTS AND DISCUSSION

The results of the three purification methods are shown in Table 1. It is apparent the Et-OH method yields more DNA/ml than either spooling the DNA or the CTAB method. When purification method is not considered, the 3 cultivars yield approximately the same amount of DNA/ml with Lemont slightly below the other 2 cultivars (Table 1). The observed difference between purification methods is significant ($F = 18.99$, 2:9 df, $P < 0.001$, Table 2). No significant difference was observed between cultivars or for the interaction between cultivar and purification method ($P > 0.129$ and $P > 0.223$, respectively).

The results of the agarose electrophoresis were somewhat surprising. Although the greatest amount of DNA was obtained using the Et-OH precipitation method, it was also the most sheared (*i.e.*, least useful) when compared to the DNA obtained from the other purification methods. For one cultivar (Tebonnet), the CTAB method yielded

A Comparison of Methods for Purification of DNA from Rice

Table 1. Amount of rice genomic DNA (ug/ml) extracted from rice categorized by purification method and cultivar.

Cultivar	Et-OH Precipitation	Spooling	CTAB
Lemont			
Trial 1	5.0	1.25	0.62
Trial 2	5.0	0.31	1.25
Tebonnet			
Trial 1	10.0	1.25	0.62
Trial 2	20.0	0.0	1.25
Newbonnet			
Trial 1	20.0	1.25	2.5
Trial 2	10.0	2.5	2.5

Table 2. Summary of amount of DNA (ul/ml) extracted from rice categorized by purification method and cultivar.

	Average Concentration	Standard Deviation
Method:		
Et-OH	11.67	6.83
Spooling	1.09	0.88
CTAB	1.49	0.86
Cultivar (combined across methods):		
Lemont	2.24	2.17
Tebonnet	5.52	8.01
Newbonnet	6.41	7.35

sheared DNA, as evidenced by DNA streaked through the entire lane, although it was not as sheared as the Et-OH method. Overall, we found less smearing through the agarose electrophoresis for DNA prepared by the spooling method. Thus we judge the spooling method to yield the best quality DNA for further analysis.

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A DATA ACQUISITION AND CONTROL PROGRAM FOR CHROMATOGRAPHIC AND SPECTROSCOPIC STUDIES

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ABSTRACT

An IBM PC compatible computer was interfaced to an Ithaco 3962 lock-in-amplifier. The computer controlled the functions of the lock-in-amplifier, acquired and stored data, and allowed for real time or off-line processing of data. Computer/amplifier connection was made via RS-232-C serial interface. Programmed in Microsoft QuickBASIC, the computer assumed the role of a dedicated chromatographic integrator. This reduced the overall instrumentation expense by eliminating a dedicated chromatographic integrator. The computer program supplied much greater flexibility in control and data interpretation. To show its utility, the program was applied to a study of the infrared emission from a flame upon the introduction of hydrogen or carbon species, respectively, in the gaseous form and as contained in organic compounds. Emission was monitored at 2.7 and 4.3 μm by an infrared radiometer.

INTRODUCTION

The objective of this project was to meet the need for a read-out device for spectroscopic and chromatographic data. These signals were being monitored by an infrared radiometer system. The radiometer system consisted of a lead selenide (PbSe) photoconductive cell, associated signal conditioning circuits, and an Ithaco 3962 lock-in-amplifier (LIA). The radiometer monitored a hydrogen/air flame into which the effluent from a gas chromatograph was routed. Organic compounds pass through a GC column at different rates, depending upon their interactions with the packing within the column. As the separated compounds eluted from the GC, they were combusted in the flame, resulting in predominantly carbon dioxide and water vapor formation. Each of these products are thermally excited in the flame and emit infrared radiation, at 4.3 μm for CO_2 and 2.7 μm for H_2O (Hudson and Busch, 1987 and 1988). This radiation produced a signal in the Ithaco 3962 LIA proportional to the emission. While initial studies could rely on simply watching the numeric read-out of the LIA, more sophisticated work required data storage and further processing.

EQUIPMENT AND METHODS

Computer equipment used included a 640K, floppy equipped IBM PC-Jr. and Zenith 12 MHz AT compatible 80286 PC. The program, written in QuickBASIC 4.5, was also run on an XT clone in the off-line mode to confirm graphics compatibility. The infrared radiometric system was set up as a flame infrared emission detector (FIRE) for gas chromatography and used the Ithaco 3962 LIA, a Varian Model 700 gas chromatograph, and PbSe FIRE detector. The PbSe device and electronics was initially described by Hudson and Busch (1988) and later modified by Hudson, Fau, Underhill, and Applequist (1990).

The Ithaco Model 3962 LIA is a phase and frequency locked, sensitive AC voltmeter (Ithaco, 1986). An LIA is used with a PbSe radiometer for several reasons. The nature of the PbSe photoconductor gives a greater sensitivity when operated in the alternating current, or chopped, mode. PbSe detection is enhanced by a factor of about 100 times in this case. Since the LIA is phase and frequency locked, many sources of noise can be discriminated against through its use. The Ithaco 3962 is also equipped with an 8088 microprocessor and IEEE-488 and RS-232-C ports for connection to external equipment. The internal programming of the 3962 supports several digital filtering and signal enhancement options. The addition of a computer system allowed a great deal of flexibility in the application of noise suppression and data handling, both 3962 internal and on acquired data. QuickBASIC 4.5 (Microsoft Corporation, Redmond, WA) was chosen as the programming language because it offered the advantages of wide acceptance, ease of programming, speed, and significant enhancements over standard BASIC (Microsoft Corporation, 1987 and 1988). Initial versions of the described program were written using the authors knowledge of interpreted BASIC. As work proceeded, various features of QuickBASIC 4.5 were incorporated. The program version described will not run under interpreted BASIC, and may not under previous releases of QuickBASIC.

Samples of reagent grade hexane were repetitively injected on the GC column, a stainless steel ¼ in. o.d. 10% OV-101 on Chromasorb W-AW (Supelco, Bellefonte, PA), using a 10 ul liquid syringe (Hamilton, Reno, Nevada). Various sample amounts were used, up to the capacity of the syringe. Helium was used as the carrier gas, hydrogen and air as flame support gases. All gases were controlled using flow meters with integral flow controllers (Cole-Parmer Instruments, Chicago, IL). Flow rates for all data presented were: helium carrier, 40 ml/min; hydrogen, 100 ml/min; air, 330 ml/min. Column temperature was held at 75 °C.

PROGRAMMING CONSTRAINTS

The overall goal of the program was to control and acquire data from the 3962, allow data storage and processing, and to present the data in a graphic display form representative of a GC chromatogram or spectroscopic display. For the infrared emission application, data would be presented with relative intensity as the y-axis in either case. The x-axis would represent time for GC studies and wavelength for spectroscopic studies. The ability to graph data in real time or data already stored on disk was required.

Control of the 3962 LIA was accomplished using the three letter commands recognized by its 8088 internal program. Each command may have an associated interrogative or passed parameter. The command 'BSS6' sent to the 3962 is interpreted as set the signal input sensitivity to the 1 mv range, while '?BSS' would return the current setting. All parameters had an associated initial level at 3962 start-up, however the program allows new settings to be selected from the keyboard, or input from a file.

Data was acquired at a rate of 1 Hz, ie, the 3962 sent a data block to the computer 1 time per second. The format consisted of a relative measurement number and the intensity data. Acquired data was plotted on the graphics screen and stored in an array until the end of an

A Data Acquisition and Control Program for Chromatographic and Spectroscopic Studies

experiment, when the data could be saved to a disk file. The array was dismensioned large enough to allow data to be collected for about 100 minutes. Data acquisition rates could be changed to give longer monitoring time or shorter response time, as needed. Baud rate for the RS-232-C line was set at 4800. An examination of system bandwidth reveals that the data transfer rate of 1 Hz is sufficient for chromatographic peaks. Such peaks normally show a width at half height of at least 5 seconds, requiring a sampling rate greater than 0.4 Hz, which has been achieved. The LIA bandwidth is determined by the time constant of the low pass filter employed. The filter was set at 1 second for the data shown, giving a bandwidth of 0.16 Hz, again exceeded by the transfer rate.

Graphic display was achieved using the IBM CGA format. The incoming data needed to fit inside the PC screen, and therefore was scaled. The integration process required that an accurate average background, or baseline, level be determined. Since chromatographic data sometimes dips below this level, the baseline was displayed slightly above the screen bottom. Since the baseline is established under conditions of background signal (the flame itself emits infrared energy) and the analytical signal was often small in comparison, the baseline simply provided a reference point for the integration. The display was then actually a window viewing a portion of the overall infrared signal.

The useful interpretation of raw data during a chromatographic experiment requires that the time from sample injection to the time of a particular peak maximum be known and that the peak height or area be known. The first parameter is known as the retention time. The retention time is a qualitative parameter since individual compounds interact differently with the column packing and the compounds exit the column at different times. Peak height or area is the quantitative information in chromatography. The peak area is actually the best parameter, giving a more accurate determination of amount. It was therefore necessary that the program be able to integrate the area under the GC peaks. This required that routines be written to recognize the beginning and ending of an actual peak, and to then integrate the area contained under the peak down to the baseline level. Commercial integrator units usually print out integrations after the signal is acquired and plotted or graphed. Therefore, the program could make use of a nonreal-time integration.

RESULTS AND DISCUSSION

In considering the goals of the program and the constraints presented by the Ithaco 3962, the program was menu driven. This menu presents a number of options, the five most important of which are the abilities to read current instrument setting, change settings, read experimental data in real time, read recorded data stored from previous runs, and to set some parameters in real time. Figure 1 shows the program main menu. The subroutines used to achieve the programs main functions are discussed below.

```
MODEL 3962 LOCK-IN AMPLIFIER INTERFACER VERSION 3.21

        1 - ENTER 3962 SETTINGS
        2 - SHOW ACTIVE 3962 SETTINGS
        3 - SET 3962 FROM FILED SETTINGS
        4 - SET SENSITIVITY
        5 - COLLECT SAMPLE
        6 - DISPLAY AND INTEGRATE SAMPLE
        7 - SAVE SAMPLE
        8 - LOAD SAMPLE
        9 - EXIT TO SYSTEM

      Enter selection:
```

Figure 1. Main menu.

In order to read current instrument settings, a series of print statements using the interrogative forms of the three letter commands followed immediately by an input were used. For example:

```
PRINT #1, "?BSS":INPUT #1,X,SS
```

was used to command the 3962 LIA to send the sensitivity setting to the computer, which ended up being stored in the variable 'S'. For the flame infrared emission detector chromatography system application, the parameters of interest were the header, sensitivity, time constant, reference or phase angle, and the error status. Often, during initial setup, one may want to set instrument parameters by hand and read them into the computer for future use. The ability to save these settings was incorporated.

The ability to enter new parameters from the computer provides remote control to the LIA. A subroutine was included to allow the operator to set many of the functions of the 3962 by selecting the functions and their parameters from a menu. Functions used less often, not included in the menu, could be entered by the operator as three letter commands. Figure 2 show the functions menu, while Figure 3 is an example for setting the sensitivity of the 3962 LIA.

```
The following can be set:

 1 - Analysis frequency range (Hz)
 2 - Reference mode
 3 - Sensitivity (V)
 4 - Time constant (s)
 5 - Automatic setting
 6 - Auto-ranging
 7 - Auto-tuning
 8 - Reference phase offset value
 9 - Meter sensitivity
10 - Header
11 - Sampling interval and output interval
12 - OTHER

Press RETURN to end selection.
Enter selection:
```

Figure 2. Set functions menu (main menu item 1).

```
BTCx - Time constant (s)

POSSIBLE SETTINGS ARE: 0: 1m     5: 300m
                       1: 3m     6: 1
                       2: 10m    7: 3
                       3: 30m    8: 10
                       4: 100m   9: 30


Press RETURN to cancel.
Enter the setting:
```

Figure 3. Sensitivity Selection Menu (set functions menu item 3).

The most important single feature of the program is to plot or graph the data, both in real time and stored, to the computer screen. The Color Graphics Adapter (CGA) allows black and white images to be formed in a 200 (Y) by 640 (X) matrix (high resolution mode). X-axis data corresponds to run time, and run time may vary from as little as 2 minutes to as long as an hour in practice. Long GC runs were handled in two ways depending on whether real time or stored data were being plotted. In real time, X-axis data is directly plotted to the screen. At one Hz data collection rate, data points corresponding to from one to 640 seconds can be displayed at once. To display points above 640, the graphics screen is erased, and points are plotted beginning at the left side of the screen. In other words, after point 640 is plotted, the screen

is erased and point 641 is plotted at the screens left edge. This is repeated each 640 points, until the end of the run is reached. Once data is stored, it may be recalled and redisplayed. Still using the 200 by 640 mode, the data may be plotted in a user specified window, in compressed or expanded form. Figure 4 shows data containing three obvious peaks,

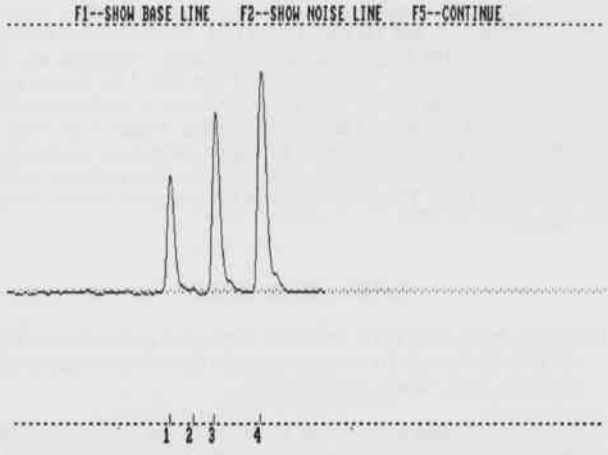

Figure 4. Chromatographic data, for multiple injections of n-hexane, redisplayed as recorded.

redisplayed as collected. Figure 5 shows the same data redisplayed, but scaled so that 225 data points are displayed. The screen "window" can be set to display any particular portion of the stored data, such as points 125 to 350, to allow various data features to be compressed or expanded for examination.

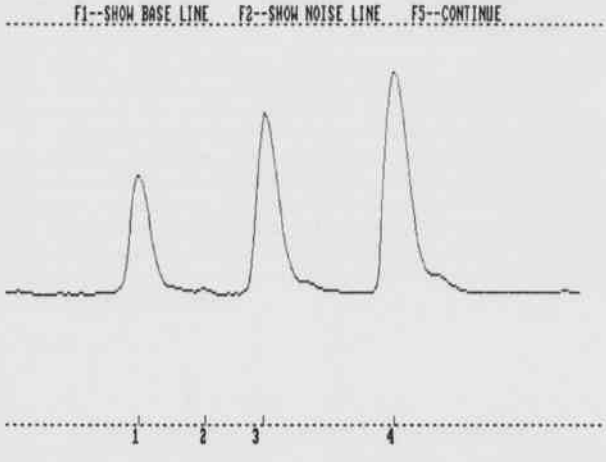

Figure 5. Chromatographic data, X scale expanded.

Y-axis, or intensity, data must be scaled to fit the screen for both modes of data display. In the real time mode, Y scaling is performed such that the bottom and top of the screen correspond to zero and full scale setting of the 3962 LIA. For data collected with a 10 mv LIA sensitivity setting, the graphics screen would represent approximately zero at the bottom and 10 mv at the top. Redisplayed data may employ a user determined scaling factor. When the data file is read into the computer, an analysis of the data is performed which reveals several parameters including baseline, noise level, and an appropriate scale factor. The user may choose the option of setting the displayed "window" to any value. Fig. 6 shows data enlarged to reveal a small peak not clear in Fig. 4. The program "recognized" this as a peak, and so labeled it.

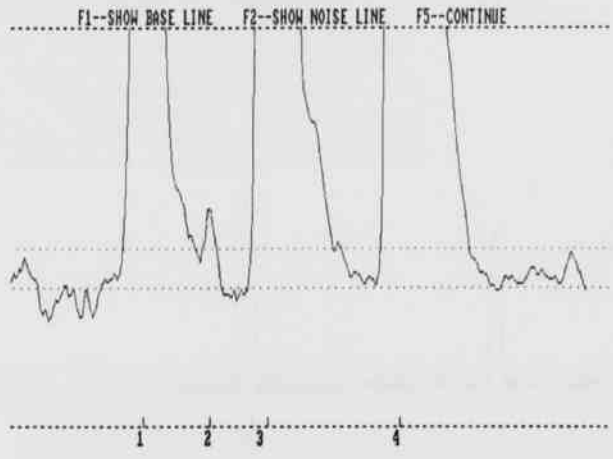

Figure 6. Chromatographic data, X and Y scales expanded.

Another feature found in redisplay of data is the raw/corrected data setting. Raw data is displayed within the window chosen, relative to actual zero. Keep in mind that the chromatographic baseline is actually the steady state hydrogen/air flame background. This background represents a large signal to the LIA (the DC offset value). Since the chromatographer is interested in the difference in the signal upon introduction of separated components from the GC column, the raw data display may not allow viewing of small peaks under high magnification "windowing". The corrected data setting displays the data centered on the average value, offset by a noise adjustment value, discussed in more detail below.

To correctly integrate peaks, a method of peak recognition must be incorporated into the program. The method must be fairly immune to noise, but still allow a proper level of sensitivity. This program has used two approaches to handling this problem. Both methods were used on the redisplayed data, as this was simpler to handle, and involved analyzing the first several data points recorded (defaults to 60). Method one averaged the data, which gives a baseline value and set a noise limit of the average + 10%. While this method worked in many cases, it would obviously fail for small signals superimposed on a large DC offset value, and for very noisy signals recorded with a small DC offset value. Method two evolved to correct these problems. This method averages the data and finds the standard deviation of the data (noise). The baseline is still the averaged value, but the noise limit is set at three times the standard deviation (99% confidence level). While this improved peak recognition compared to method one tremendously, it still detected erroneous peaks. An additional parameter of requiring a number of consecutive data points (default = 5) above the noise limit for peak recognition was added. This reduced falsing to a negligible level.

Integration was also handled two different ways. The first method simply summed individual data points minus the signal average. This technique was used with the first method of peak recognition, and, while functional, was changed to a more advanced technique, less prone to error. The second and currently used method involves the application of Simpson's Rule to individual points minus the baseline to more closely approximate the area under the peaks. Additionally, the points im-

mediately before and after peak recognition are included in peak integration. Fig. 7 shows a simulated chromatographic run, in which peak two has twice the area of peak one, under noisy conditions. Table 1 shows the integrated areas for peaks one and two for conditions of noise and no-noise. A good correlation between these values is seen, indicative of good performance. The routine to generate noise and peaks for simulation is included as a test mode in the program.

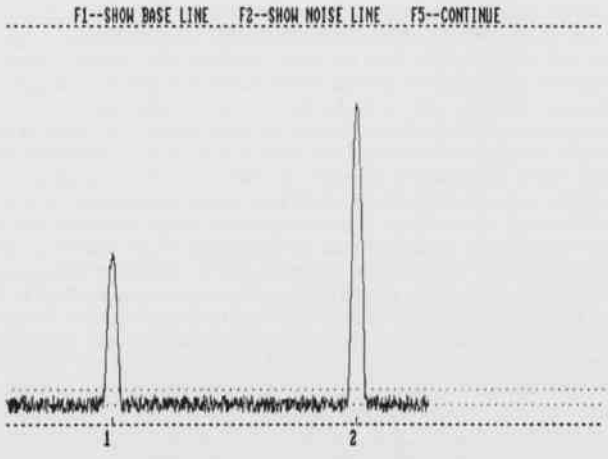

Figure 7. Simulated data showing the effect of noise on program integration routine.

Table 1. Noise/No Noise Simulted Data Integration Results

Peak No.	Location	Area
1a	220	2.359518×10^{-4}
2a	732	4.754066×10^{-4}
1b	220	2.400004×10^{-4}
2b	732	4.800007×10^{-4}

"a" peaks taken under conditions of "noise"
"b" peaks, no noise conditions.

CONCLUSION

The authors feel that the current program offers the user of an Ithaco 3962 a great deal of versatility in the collection and processing of data. While the application presented has involved gas chromatography, any application which involves an intensity versus time domain may be acquired, stored, and displayed. For example, the authors are currently constructing a spectrometer for infrared emission studies. The program will be used to collect intensity versus wavelength (time scanned) data. Other current work is underway to include commands to allow use with the Ithaco 3961 LIA and 3981 PC board LIA. Modifications will consist of changes in the file opening and three letter command set, and should allow higher data collection rates. The 3981 LIA system is internal to the computer chassis, with the exception of a small preamplifier unit, and further simplifies the instrumentation. Future work may include options to allow the program to acquire data from an analog to digital interface, which will allow application to other methods besides those using an LIA. Those interested in the program should contact the authors.

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PHOTOACOUSTIC DETECTION OF CARBONACEOUS ATMOSPHERIC AEROSOLS

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ABSTRACT

The role of carbonaceous aerosols in the atmosphere as a risk factor in climatic changes and health effects and state-of-the-art monitoring processes are briefly presented here. In particular, development of a photoacoustic technique for measuring the concentration of carbonaceous particles is discussed. The photoacoustic measurement is based upon detection of pressure waves generated by localized time-dependent heating of air inside the photoacoustic chamber. Heating of air inside the chamber is due to absorption of visible laser radiation by carbon particles prsent inside the chamber. The laser radiation is chopped, and the resultant pressure signal produced by subsequent heating and cooling of the gas is monitored using a microphone. Sensitivity of this photoacoustic technique and its application in monitoring soot particles in the atmosphere is discussed.

INTRODUCTION

Absorption of solar radiation by atmospheric aerosols can be a major influence on climate and on the radiation budget determining the temperature of the Earth. The troposphere is the atmospheric region most directly affected by man's activities; airborne particulates have greatly increased due to the combustion of fossil fuels in industrialized countries. The structure and composition of these airborne particulates are extremely variable, depending on meterological conditions, emission sources, and geographical locale.

Measurement of aerosol light-absorption coefficients are directly valuable for studies of atmospheric visibility, radiative transfer, and atmospheric heating rates, while determination of particulate concentrations are of direct value for source monitoring.

Experimental data on the absorption of solar radiation by aerosols have been obtained using 3 different methods:

1) airborne devices have been used to determine the radiative flux divergence in layers of the atmosphere which, on subtracting the calculated gaseous component, yields the aerosol absorption component (Roach, 1966; Robinson, 1966; Kondratyev *et al.*, 1974; Valero *et al.*, 1982). Careful instrumentation is necessary and long term averaging is required due to inhomogeneities in the surface albedo.

2) absorption analysis of filter-collected aerosol particle samples has been carried out (Fischer, 1973; Weiss *et al.*, 1979; Bennett *et al.*, 1981). There is, however, the possibility that the sample will be modified by collection, especially in the case of liquid or liquid coated particles.

3) absorption coefficients have been inferred from scattering properties of the aerosol (Eiden, 1971; Grams *et al.*, 1974). This requires detailed information on the scattering properties to carry out the required Mie calculations.

INTERACTION OF LIGHT WITH PARTICLES

Light extinction in a homogeneous medium is described by the Beer-Lambert Law.

$$I/I_o = \exp(-\beta_{ex}L) \quad (1)$$

where I is the light intensity at a distance L into the medium, I_o is the incident or initial intensity, and β_{ex} is the extinction coefficient for the medium at the specific frequency or frequencies of the incident light.

Extinction is due to absorption and scattering of the electromagnetic energy. The extinction coefficient is the linear sum of the absorption (β_{ab}) and scattering (β_{sc}) coefficients.

$$\beta_{ex} = \beta_{ab} + \beta_{sc} \quad (2)$$

The extinction cross section (α_{ex}) of a particle is defined as the hypothetical area normal to the incident radiation that would geometrically intercept the total amount of radiation actually extinguished by the particle (Weast, 1980-81). The extinction coefficient of a monodisperse aerosol can be considered to be the product of the extinction cross section for individual elements (α_{ex}) of the medium and the number concentration, N, of those elements.

$$\beta_{ex} = N\alpha_{ex} \quad (3)$$

The amount of radiant power absorbed and scattered by the particle is given by,

$$P_{ex} = I_o\alpha_{ex} \quad (4)$$

where P_{ex} is the power absorbed and scattered from the incident beam of intensity I_o. The extinction cross section of a particle is a linear summation of components due to absorption and scattering.

$$\alpha_{ex} = \alpha_{ab} + \alpha_{sc} \quad (5)$$

Photoacoustic techniques (Patel and Kerl, 1977; Faxvog and Roessler, 1979; Szkarlat and Japar, 1981; Roessler, 1984; Roessler and Faxvog, 1980; Terhune and Anderson, 1977; Bruce and Pinnick, 1977; Foot, 1979; Weast, 1980-81) offer a method of measuring absorption of light by aerosol particles directly. The basic theory behind photoacoustic detection is quite simple. Light absorbed by a sample will excite a fraction of the ground-state molecular population into higher energy levels. These excited energy states will subsequently relax through a combination of radiative and nonradiative pathways. The nonradiative component will ultimately generate heat in the localized region of the excitation light beam resulting, when the light intensity is modulated, in a pressure wave that propagates away from the source, or in the case of a small closed cell, a modulated pressure rise which may be detected by a sensitive microphone. A schematic of a typical photoacoustic apparatus for aerosol light absorption is illustrated in Fig. 1.

The spectrophone provides a means of continuous monitoring of ambient aerosol particulate concentrations that is far less time consuming than filter collection techniques. The time response of the spectrophone is on the order of seconds, with a detection capability of below 10^{-8} m^{-1} (Patel and Kerl, 1977).

Photoacoustic Detection of Carbonaceous Atmospheric Aerosols

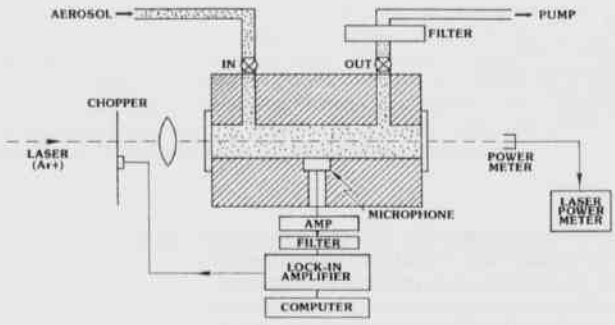

Figure 1. Schematic of photoacoustic measurement apparatus for aerosol light absorption studies.

The absorption and scattering cross sections, α_{ab} and α_{sc}, are defined in the same manner as the extinction cross section. When all scattering is negligible or has been subtracted from the extinction, Eq. (2) reduces to

$$I/I_o = \exp(-\beta_{ab}L) \quad (6)$$

Normalizing β_{ab} to the mass concentration M of particles per volume V gives the specific absorption coefficient β_{ab}/M_v, where the specific mass $M_v = M/V$.

SCALING LAWS FOR PHOTOACOUSTIC SYSTEMS

The first important parameter is the responsivity R, of the system. It is a measure or the electrical signal produced by the microphone for a unit amount of power absorbed by the aerosol particulates. Convenient units for R are $(V/watt \cdot m^{-1})$.

For particle concentrations of interest, the microphone signals, S, of the photoacoustic system (Faxvog and Roessler, 1979) is therefore

$$S = R \cdot A_a \cdot M \cdot W_o \quad (7)$$

where W_o is the time-averaged incident power and R is the responsivity of the cell. M is the aerosol mass concentration, and A_a is the specific aerosol absorption coefficient.

The specific absorption coefficient A_a, is defined by

$$A_a = \beta_{ab}/M_v \quad (8)$$

System sensitivity is defined by the absorption coefficient

$$\beta_{ab} = \alpha_{ab} \cdot C \quad (9)$$

where α_{ab} is the absorption cross section of the species being measured, C is the fractional concentration of the absorbing species. In analyzing any photoacoustic method one must first develop a theoretical description of optimizing the optical and acoustic phenomena, then identify those factors which limit sensitivity of the device. In essence, the optimization is reduced to consideration of the following parameters:

(a) maximizing the amount of laser energy absorbed by the gas or aerosol by either boosting the incident power or minimizing reflection losses.

(b) minimizing the background signal by reducing absorption on those surfaces in direct contact with the sample gas or aerosol (i.e. windows, cell walls) and;

(c) minimizing the effect of those loss mechanisms which one can control by appropriate system design.

ABSORPTION CHARACTERISTICS OF CARBON MIXTURES

For the purpose of this work we define 2 different ways in which soot might be included in atmospheric aerosols:

1) External mixture. The soot and non-soot aerosols exist in the atmosphere as distinct particles which are mixed without interacting. In this case the properties of the mixture are sums of the properties of the individual distributions.

2) Internal mixture. The soot is deposited as a shell on the outside of a solid non-soot particle or is the core of a particle with a sulfate solution shell.

The fact that soot as a core is more effective than soot as a shell in absorbing radiation is due to 2 effects. A solution sheath around the core acts to focus photons on the core, thus increasing its effective cross-section, whereas a particle with a soot shell has a greater tendency to reflect or refract photons than does a particle with a solution shell due to the larger real part of the index of refraction (Toon and Ackerman, 1981).

EXPERIMENTAL STUDY

Three spectrophones were tested for their sensitivity in making light absorption measurements: 1) a Burleigh Instruments, Inc. PAS-100 non-resonant spectrophone, (Fig. 2); 2) a laboratory built Helmholtz resonant spectrophone, (Fig. 3); and 3) a laboratory built longitudinal mode resonant spectrophone (Fig. 4). For 1 watt of average power from the

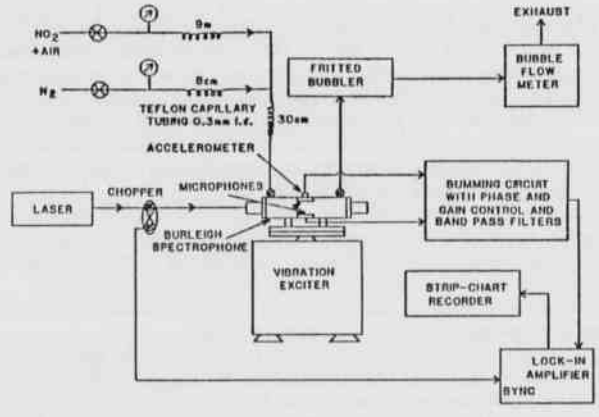

Figure 2. Experimental arrangement for making light absorption measurements and vibration measurements with the Burleigh spectrophone.

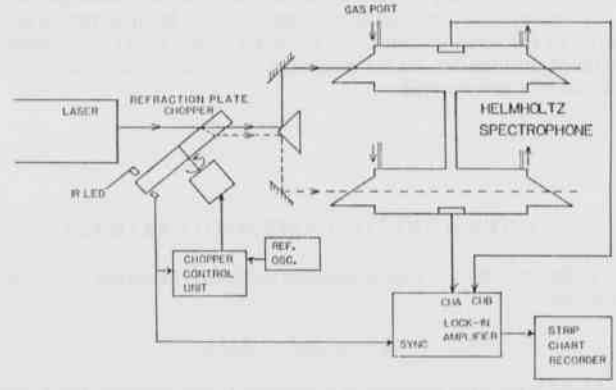

Figure 3. Experimental arrangement with the "Dual-Drive" Helmholtz resonant spectrophone using a slotted refraction plate chopper.

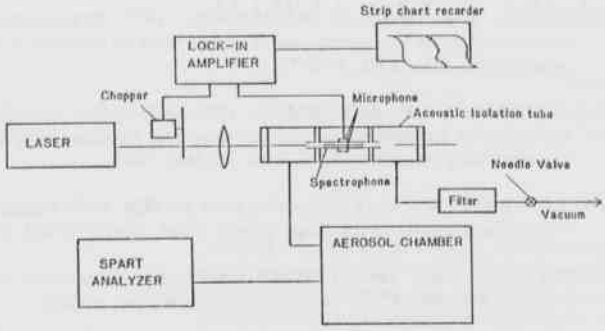

Figure 4. Experimental arrangement for measuring light absorption by aerosols.

488 nm line of an argon-ion chopped laser beam the sensitivities for the 3 spectrophones were 6.5×10^{-6} m^{-1}, 2.5×10^{-6} m^{-1}, and 3.0×10^{-7} m^{-1}, respectively. The sensitivities are for a 1 second time constant on the lock-in amplifier and for a signal-to-noise ratio of one. The noise levels were measured under ambient laboratory conditions with no absorber in the spectrophone. Nitrogen dioxide, NO_2, was used for calibrating the spectrophones because it exhibits strong absorption of visible light and because published absorption spectra and absorption coefficients were available from literature. The NO_2 concentration was monitored using the wet chemical reagent technique developed by Saltzman (1954). The longitudinally resonant spectrophone was found to provide the greatest sensitivity of the three. The first longitudinal resonance was at 814 Hz. A Radio Shack 270-092A electret condenser microphone was mounted at the longitudinal midpoint of the tube. This tube was housed inside an acoustic isolation chamber. The responsivity of the longitudinally resonant spectrophone was about 120 mV ppm^{-1} W^{-1}. The resulting sensitivity for NO_2 detection was about 0.7 ppb with 1 watt of chopped laser power and optimum noise conditions.

Photoacoustic measurements were made on aerosols of cigarette smoke, sodium chloride, and polystyrene latex spheres (PLS). Simultaneous measurements of the particle size distribution and the approximate number concentration were made using a Single Particle Aerodynamic Relaxation Time (SPART) analyzer (Mazumder *et al.*, 1979). Figure 5 shows a strip chart recording of the photoacoustic signal for cigarette smoke using the longitudinally resonant spectrophone. The

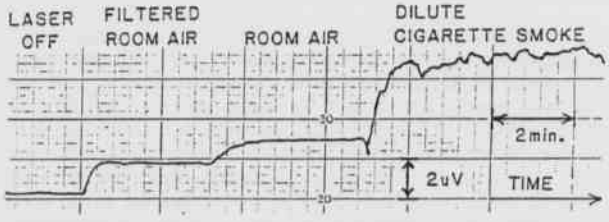

Figure 5. Strip chart record of measurements of the absorption of light by aerosols using a longitudinally resonant spectrophone.

count median aerodynamic diameter was about 0.6 μm. Extrapolation of the signal down to the background noise level gave a detection limit of about 3×10^6 particles/m^3 for 1 watt of average laser power. However, this corresponds to less than 1 particle in the illuminated volume at a time. The count median aerodynamic diameter for the NaCl particle was about 0.9 μm. The photoacoustic signal for the NaCl particles was found to be about 3 orders of magnitude smaller than for the cigarette smoke. A dependence on relative humidity was also observed. The detection limit for the PLS (diameter = 1.09 μm) was estimated at about 5×10^8 particles/m^3. Some of this signal may have resulted from the high scattering intensity of the particles.

A detection limit for 1 um carbon particles was calculated to be approximately 0.39 μg/m^3. Measurements on cigarette smoke gave an extrapolated detection limit of 0.39 μg/m^3. For NaCl and PLS the mass detection limit is 2.7 mg/m^3 and .35 mg/m^3, respectively.

CONCLUSIONS

Future work will include the development of a prototype photoacoustic system for the simultaneous measurement of particle size, light absorption, and light scattering characteristics of carbon particulates on a single particle basis. The measurements will be performed in a cell having 3 functions: (1) suspending the test particle in a electrodynamic trap, (2) a photoacoustic cell to measure light absorption, an (3) a relaxation cell to measure aerodynamic diameter of the particle as well as light scattering intensity. Completion of this work will provide valuable insights into the spectral wavelength dependency, shape, and chemical composition of carbonaceous aerosols and their relationship in climate modification.

ACKNOWLEDGMENT

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HEMATOZOA OF COMMON GRACKLES (*QUISCALUS QUISCULA VERSICOLOR*, VIEILLOT) IN CENTRAL ARKANSAS

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ABSTRACT

During the years 1977-84, 118 bronzed grackles, *Quiscalus quiscula versicolor*, Vieillot, of 132 examined were found infected with hematozoa. The eight species of symbionts collected from the infected birds included two microfilarial species (*Chandlerella quiscali* and *Eufilaria hibleri*), five apicomplexans (*Haemoproteus quiscali, Leucocytozoon fringillinarum, Plasmodium matutinum, P. vaughani, P.* sp.) and a flagellate (*Trypanosoma ontarioensis*). *P. matutinum* and *T. ontarioensis* represent new host records and all the protozoans represent new locality records. Comparisons are made of symbiont prevalance and diversity as this relates to seasons of the year, sex and age of the host. Comparisons are also made with previous studies on this subspecies.

INTRODUCTION

The study of avian hematozoa constitutes an intriguing ecological investigation because the symbionts share a common habitat. In some instances the organisms are present in the plasma and in other instances within the blood cells. Microfilaria of nematodes and asexual stages of protozoans constitute the symbionts of this study. Both of these groups rely on the blood as a medium in which they find nutrients and a vehicle through which they are transmitted to the insect intermediate or definitive host. Microfilaria and trypanosomes are solely plasma inhabitants while the species of *Plasmodium, Leucocytozoon* and *Haemoproteus* spend most of their development time within the blood cells. The microfilaria, unlike the protozoans, do not proliferate within the blood but are released from adult fertilized nematodes of either *Chandlerella quiscali* (von Linstow, 1904) in the cerebrum or *Eufilaria hibleri* (Granath, 1981) in the subcutaneous connective tissue. The microfilarial stage is purely the transmission stage as the bird is the definitive host and ceratopogonids the intermediate hosts. In many filarial infections there is a diurnal periodicity of increase in microfilarial numbers in the peripheral blood. Protozoans also have developmental stages in other organs with at least the infective stage being present in the blood. Proliferation of the protozoans occurs in the bird, but the definitive host is an insect in all but one instance. Trypanosomes do not have a known sexual stage and the question of definitive host becomes moot. In this latter case, vegetative proliferation occurs in both the insect and the vertebrate host.

The common grackle, *Quiscalus quiscula,* has been divided into three major subspecies. The bronzed grackle, *Q. q. versicolor* Vieillot, has a breeding range generally extending from the eastern slopes of the Rocky Mountains covering most of Texas to the western slope of the Appalachian Mountains and into New England. The northern boundary reaches far into Canada (Maxwell, 1965). East of the Appalachians, there exists the purple grackle *(Q. q. stonei)* and the coastal Florida grackle *(Q. q. quiscula).*

Substantial hematozoan work has been done on the purple grackle, but few studies have been made concentrating on the hematozoa of the bronzed grackle. There have been more studies in which bronzed grackles have been incidental to a larger study focusing on many species. Bennett, *et al.* (1982) compiled a documentation of bird host-hematozoan associations that enables an investigator to form a list of species of hematozoa from most species of birds. From this source, the following were documented as being present in bronzed grackles: Microfilaria of *C. quiscali;* intracellular apicomplexan species *Leucocytozoon fringillinarum, Plasmodium cathemerium, P. circumflexum, P. elongatum, P. relictum (= P. praecox), P. vaughani (= P. hexamerium); Haemoproteus fringillae/orizivora, H. quiscalus* and the intercellular flagellate, *Trypanosoma avium.* Tables 1 and 2 list the hematozoa recorded above. Table 1 lists the symbionts reported only by genus. Table 2 records those cases in which the symbiont species is identified. The tables also list the genera and species reported since

Table 1. Hematozoa Genera (Species unknown) from Bronzed Grackles

AUTHORS	YEAR	STATE	INF/EX	HAEM	LEUC	PLAS	TRYP	MICR
AL-DABAGH	1964	OH	1/4	1				
BENNETT, CAMERON, WHITE	1975	NB	12/15	4	9	1		
BENNETT, FALLIS	1960	SONT	58/80	7	52		6	16
IMMATURES			13/24		13		1	
NESTLINGS			8/99		8			
CLARKE	1946	ONT	2/3		2			1
COATNEY, WEST	1938	NE	1/1					
IMMATURES			1/1					
FARMER	1960	IA	5/16	1	5	1	1	1
HERMAN	1935	NY		X				
HUFF	1939	IL	63/128	45	4	7	1	X
FLEDGLINGS				3				
NESTLINGS				4	1			
MANWELL	1951	NY	56/75	30	45	8		
ROBINSON	1961	OH	1/2					1
SACHS	1953	IL	3/4	3	3			X
SMITH	1967	OH	23/26	13	16	2		
STABLER, KITZMILLER	1970	CO	4/5	2			1	3

Table 2. Hematozoa Species Reported from Bronzed Grackles (Number of Birds Infected)

AUTHORS	YEAR	STATE	PR	PC	PE	PV	TA	HQ	HL/O	LF	CQ	BH
AL-DABAGH	1964	OH						1 *				
BENNETT, CAMERON,									4 *	9 *		
WHITE	1965	NB										
COATNEY, WEST	1938	NE					1	1				
IMMATURES								1				
FALLIS, BENNETT	1961									1		
FALLIS, BENNETT	1962									1		
GRANATH	1981	IL										86
GRANATH, HUIZINGA	1978	IL									X	
HERMAN	1935	NY		X								
HERMAN	1938	NY		1								
HERMAN(IRCAH)	1982			X								
HUFF	1939	IL	3	2	3							
NESTLINGS			1		1							
IRCAH	1982					X						
MANWELL	1951	NY	1	3								
MANWELL, HERMAN	1935	NY		1								
ODETOYINBO, ULMER	1960	IA									X	
SACHS	1953	IL					1					
STABLER, KITZMILLER	1970	CO					1 *					

*Identified by IRCAH after publication.

Hematozoa of Common Grackles (*Quiscalus quiscula versicolor*, Vieillot) in Central Arkansas

the 1982 publication of the *Host-parasite catalog of avian hematozoa*. The following have been added. Granath (1981) described adults and microfilaria of *E. hibleri* from Illinois grackles. Woo and Bartlett (1982) described *T. ontarioensis* from *Corvus brachyrhynchos brachyrhynchos* in Ontario. *Chandlerella quiscali* microfilaria have been reported in the host in Illinois by Granath and Huizinga (1978) and in Iowa by Odetoyinbo and Ulmer (1960). Adults of both microfilarial species have been recorded previously in the birds of this study in Arkansas by Johnson (1984).

No literature is available comparing the hematozoa in male and female hosts. Only a few studies detailed parasitism in immature birds. Coatney and West (1938) described *Haemoproteus quiscali* from a hatching year (HY) bronzed grackle in Nebraska. Huff (1939) reported *Leucocytozoon, Haemoproteus, Plasmodiium relictum* and *P. elongatum* from nestling grackles in Illinois. Farmer (1960) found *Plasmodium* in HY birds in Iowa. Bennett and Fallis (1960) reported hematozoa from adult and immature grackles in Algonquin Provincial Park in Ontario. The following hematozoans were obtained from 58 of the 80 adults they examined: *Trypanosoma, Leucocytozoon, Haemoproteus* and microfilaria. Of the 24 immatures, 13 were infected with *Leucocytozoon* and one of those additionally with *Trypanosoma*. The authors found *Leucocytozoon* infections in eight of 99 nestlings 9-14 days of age suggesting the early onset of parasitism by the latter genus. Multiparasitism in avian hematozoa is apparently widespread but has been only incidentally reported. The immatures above indicate the qualitative compatibility of *Leucocytozoon* and *Trypanosoma* as dual infections. Clarke (1946) indicated an infection of *Leucocytozoon* with microfilaria. Smith (1967) reported dual infections of *Leucocytozoon* with *Haemoproteus* in one case and with *Plasmodium* in another. All of the above suggest a high frequency of dual and perhaps greater multiparasitism.

This study focuses on the migrant and non-migrant bronzed grackles of Arkansas and embraces three seasons: winter, pre-breeding and post-breeding. The first two seasonal samples contain migrants from the north while the third sample contains some migrants from the south as well as Arkansas adults and Arkansas derived juveniles. Since both age and sex are plausible affecting variables, the study has included those distinctions. Earlier studies of the bronzed grackle symbionts have been confined to the northern sections of the United States and southern Canada and there has been little documentation of the hematozoa of wintering and pre-breeding birds. Over an 11-year period the author has banded over 11,000 Arkansas grackles between February 1 and April 15. Recoveries indicate that the migration pattern north from Arkansas is north/northwest or away from the regions in which previous grackle hematozoan studies have been made.

The purpose of this study is to use new distributional data in the context of varying space, time and host parameters to glean insights into the relationships between the host and its symbionts and between the symbionts. The presence of the host in Arkansas throughout the year presents an opportunity to study the distribution of hematozoa from bronzed grackles involving several variables. These include geographic location, season of the year, age of the host and sex of the host. In addition the number of different species of hematozoa in the bird provides a useful analytical system in determining the multiparasitism aspects of infections and thus gives information on the interactive synergism or antagonism of the symbionts in the common habitat. Finally, it is possible to ascertain which symbionts are acquired in Arkansas and the relative magnitude of the pre-patent period in the young bird.

MATERIALS AND METHODS

One hundred thirty-two bronzed grackles were examined in Conway, AR (35° 05 'N 92° 27 'W) between 1977 and 1984. Fifteen adult females and 13 adult males were screened from December and January 1982 and 1983. These wintering grackles are designated ARWAHY. Ten adult females and ten adult males were examined during the pre-breeding period, March 1984, and are designated ARPRBAHY. Eighty-four grackles were collected during the post-breeding period (ARPOB) in August-September 1977 (11), June-August 1980 (21) and 1982 (52). The post-breeding collection included 47 juvenile birds and 37 adult birds of both sexes. Sex and age determinations were done by internal examination. The presence of a bursa of Fabricius was used to identify the juvenile birds.

All birds were collected using Glenhaven live traps baited with hen scratch or popcorn. The hosts were dispatched by thoracic constriction and the blood removed immediately from the heart auricles. All examinations were made during the daylight hours. Smears were sent to the International Research Centre for Avian Hematozoa in St. Johns, Newfoundland (IRCAH). Dr. G.F. Bennett and Madonna Bishop supervised fixation, staining and reading of the smears. Their procedure involved looking at 100 fields on each slide using a 40X oil immersion objective.

The following acronyms are used to economize on space. AR = Arkansas, W = Winter, PRB = Pre-breeding, POB = Post-breeding, AHY = Adult (After hatching year), HY = Hatching year, CQ = *Chandlerella quiscali* microfilaria, EH = *Eufilaria hibleri* microfilaria, LF = *Leucocytozoon fringillinarum*, HQ = *Haemoproteus quiscali*, HL/O = *H. fringillae/orizivora*, PV = Plasmodium vaughani, PM = *P. matutinum*, PC = *cathemerium*, PE = *P. elongatum*, PR = *P. relictum*, PN = undetermined species of *Plasmodium* belonging to the Novyella group, TO = *Trypanosoma ontarioensis*, TA = *T. avium*. The acronyms MICR, TRYP, PLAS, LEUC, HAEM stand for microfilaria or genera of the above protozoa. The usual arconyms are used for the states with SONT indicating southern Ontario and NB, New Brunswick. INF always refers to the number infected and PCT to the percent infected. EX indicates the number examined.

DISCUSSION

One hundred eighteen of 132 examined birds were parasitized by at least one of eight hematozoan species. Fifty birds had one symbiont species, 56 birds had two, 11 birds had three and one host had four different parasites.

Arkansas wintering grackles were found to have three diferent hematozoan symbionts: CQ, EH, LF (Table 3). EH was always coupled with the dominant symbiont, CQ, while the LF was so coupled in one case and not the other. Microfilaria predominated in this adult population. Pre-breeding birds housed the same three symbionts but added a fourth:

Table 3. Bronzed Grackle Hematozoa by Season and Age

	W	PRB	POBAHY	POBHY	TOT	PCT
CQ	22	18	30	8	78	59.1
EH	9	7	30	20	66	50.0
HQ	0	0	5	25	30	22.7
LF	2	2	2	0	6	4.5
PV	0	1	1	2	4	3.0
PM	0	0	1	6	7	5.3
PN	0	0	0	2	2	1.5
TO	0	0	1	1	2	1.5
INF	23	19	35	41	118	
NO.	28	20	37	47	132	
PCT	82.1	95.0	94.6	87.2	89.4	

PV. However, the dominant microfilarial species again dwarfed the infections by the protozoans. All the EH were in hosts that also had CQ. Only one of the protozoan infections was a solitary infection.

The post-breeding population presented opportunities to look at the role of age, sex and year as well as season in relation to species distribution. When the years 1977, 1980 and 1982 are compared (Table 4) as

Table 4. Number of Hematozoa Species in ARPOB Birds

YEAR	0	1	2	3	4	TOTAL
1977	1	5	4	1	0	11
1980	2	6	9	3	1	21
1982	4	17	24	6	1	52
TOTALS	7	28	37	10	2	84
PERCENT	8.3	33.3	44.0	11.9	2.4	

to number of species per bird it is apparent that the variation over the years is minor and that the usual number of symbionts per host is one or two. When the same group is separated by sex and by age (Table 5) no difference appears concerning the sex of the host and the number

Table 5. Hematozoa of ARPOB Grackles

Percentage of number of species vs age and sex

	0	1	2	3	4
HY(N=47)	12.8	44.7	29.8	12.8	0.0
AHY(N=37)	5.4	13.5	67.6	10.8	2.7
MALE(N=36)	8.3	30.6	47.2	13.9	0.0
FEMALE(N=48)	10.4	31.3	45.8	10.4	2.1

of species of hematozoa. The post-breeding adults and juveniles each have seven species of symbionts in the samples. However, the number of different symbiont species per host is greater in the adults than the juveniles. This is a seasonal event since the adults enter the breeding season with a parasitic legacy. As juvenile birds progress through the summer the initial high frequency of HQ decreases as EH frequency increases and CQ begins to appear (Table 6). Since all the juveniles were hatched in Arkansas, the seven symbiont species found in that age group were contracted in the state. The adults suggest an immunity to HQ since this frequency is low throughout the summer while both EH and CQ frequencies are high (Table 7). The low CQ frequency in the young birds suggests a longer pre-patent period for that species compared to the other microfilarial species.

If the data from the tables are consolidated to show the compatibility of the eight symbionts toward one another in a common host, it is

Table 6. Juvenile Infection Numbers by Month

	JUNE	JULY	AUG	SEPT
NUMBER	14	13	13	7
EH	1	9	7	3
CQ	1	2	3	2
HQ	9	9	3	4
PM	2	2	2	0
PN	1	0	1	0
PV	0	1	0	1
LF	0	0	0	0
TO	0	0	1	0

Table 7. Adult Grackle Infection Numbers by Month

	JUNE	JULY	AUG	SEPT
NUMBER	11	12	12	2
EH	9	11	10	0
CQ	9	8	12	1
HQ	2	2	0	1
PM	0	0	1	0
PN	0	0	0	0
PV	0	0	1	0
LF	1	1	0	0
TO	1	0	0	0

seen that the dominant symbionts CQ, HQ and EH were found in hosts with each of the other seven. The other five species only showed one other association (PM-PV), but since the frequency of other cases of infection was small the likelihood of dual infections would be expected to be rare. There is no evidence for antagonistic effects between any

of the symbionts. Of the 27 possible dual combinations between the eight hematozoans, 22 were recorded. Those not seen would be predicted to be low probability events. The high frequency with which EH and CQ are found together indicates no antagonism and perhaps even a synergism in which ontogenetically EH enhances infections with CQ.

This study has produced new locality records for four protozoan hematozoans in juveniles and five in adult Arkansas bronzed grackles. *T. ontarioensis* and *P. matutinum* comprise new host records. The dominant hematozoan symbionts in Arkansas adult grackles are the microfilaria of *Chandlerella quiscali* and *Eufilaria hibleri*. The dominant symbiont in the immature birds is *Haemoproteus quiscali*. The prevalence of infection in the other protozoan species is low. *E. hibleri* develops during the summer more rapidly than *Chandlerella quiscali*. As the year progresses the number of hematozoan species per bird increases and that is also true as the bird continues to age. However, in a seven-year-old banded and recovered bird only CQ was present. The breeding season is associated with greater insect activity (simuliids, culicids, hippoboscids, ceratopogonids) and thus the opportunity for transmission of all the hematozoans mentioned in this paper. Sex of the host apparently is not a determining factor in the prevalence and diversity of infections.

Bennett and Fallis (1960), referring collectively to many species of birds in Algonquin Park, Canada, state, "*Leucocytozoon, Trypanosoma,* and *Haemoproteus* were more prevalent among immature birds during June and July, and more birds had high parasitemias during the same period, than in August and September." In bronzed grackles specifically they found a high prevalence of *Leucocytozoon* in all ages of birds with all 13 immature birds examined infected. A very early onset of this infection is documented in the natural infections in eight nestlings. In Arkansas *Haemoproteus,* prevalence is high while the *Leucocytozoon* prevalence is low in the young birds. The simuliid vectors of *Leucocytozoon* are probably less abundant in Arkansas than in Ontario. Conversely, the ceratopogonid vectors of *Haemoproteus, Eufilaria* and *Chandlerella* may be abundant in Arkansas. Bennett and Fallis (1960) correlated insect abundance with prevalence of hematozoan infection in Algonquin Provincial Park. Huff (1939) also found *Haemoproteus* infections in young grackles in Illinois, suggesting a similar vector situation in that state.

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EDUCATIONAL SOFTWARE DEVELOPMENT USING HYPERTEXT AND EXPERT SYSTEM SOFTWARE CONCEPTS

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ABSTRACT

This paper presents two computer software concepts: hypertext and expert systems; which are useful for educational software development. Good educational software enhances the learning process and offers opportunities for faculty to provide additional materials for independent studies, which would otherwise be impossible, due to the limited time and incredible growing rate of technological progress. The hypertext concept offers the students a non-linear learning style, while the expert system concept provides explanation facilities for students to probe the logic of the systems. Both approaches are extremely useful for educational software. With the proper tools, the courseware can be implemented easily and rapidly. Educational software packages in the area of concrete technology have been currently developed for use in the Department of Civil Engineering at Christian Brothers University. They are utilized as examples. Development tools, KnowledgePro and CBC-Xpert, are also discussed.

INTRODUCTION

With the rate of technological progress, it is impossible to teach undergraduate engineering students all the latest technologies within a 4 year program. Besides being prepared for life-long learning, students must have enough basics and be aware of the latest technologies. New computer techniques can be used to develop educational software. With educational software, students can be introduced to various subject areas that are not taught in classes. The educational software can also be used to enhance the subject areas covered in classes. This paper describes 2 computer software techniques: hypertext and expert systems. The fundaments of the 2 techniques will be discussed. The hypertext software concept allows the students to select nonlinearly the sequence of his/her study. The expert system software concept allows the students to investigate the logic used by the system. Two educational software packages, developed for use in the Civil Engineering Department at Christian Brothers University, are utilized as examples. The software tools, KnowledgePro (Knowledge Garden, 1989) and CBC-Xpert (Baker *et al.*, 1990), are also discussed.

WHAT IS HYPERTEXT?

Book style organization is a highly inefficient storage and retrieval technology. Very often it is too difficult to acquire information in a sequence, other than that created by the author, and that sequence may not be tailored to your needs or prior training. Some kinds of information simply do not fit well within a linear structure. Moreover, it is extremely difficult to integrate and update large bodies of frequently changing information drawn from a large number of different sources (Remde, 1989).

Computer generated text is nothing new, so any attempt to define hypertext should begin with an effort to establish what it is not. Hypertext is not Videotext. Videotext is text screens that are displayed on a television screen for 20 second periods. It is rigidly sequential and has no capability of reader involvement. Hypertext is not Computer Assisted Instruction, at least not in the usual sense of that word. A central feature of CAI is that the student must choose a "next screen" or "previous screen" sequence only. The materials are presented in a sequence chosen by the Instructional Designer, and are punctuated regularly by examinations and review sessions. Mastery of particular information and concepts is scored and evaluations secured. Hypertext is not full text database accessed by boolean searches. In the full text database the texts are called forth in a string according to requirements of the resident search engine. Once summoned, the texts may be scanned or read in linear sequence only.

Hypertext is an alternative information delivery system. Readers are able to find just the right information in the right sequence to serve their particular needs and support their particular learning paths, or problem solving needs (Remede, 1989).

Ted Nelson, who coined the word "hypertext," defines it as "a combination of natural language text with the computer's capacity for interactive branching or dynamic display of a nonlinear text which cannot be printed conveniently on a conventional page" (Conklin, 1987). Slatin (1988) has proposed that we think of a true hyperdocument as one "characterized by high-speed machine-supported linkages between nodes organized in a non-hierarchical data structure that exist and can exist only on-line, and only in the process of being constructed by a reader who chooses the available references to pursue and those to ignore". Conklin (1987) describes it as: "Windows on the screen which are associated with objects in a database, and links are provided between these objects, both graphically (as labeled tokens) and in the database (as pointers)."

In this completely interactive system, the hypertext is composed of chunks of text called 'nodes'. The size of nodes may be determined by several things, but it is usually constrained by the amount of screen territory inherent in the hardware. In a hypertext system all nodes are text chunks, but a node may also consist of data, graphics, video, sound or computer generated simulations. In such a case the system becomes a 'hypermedia' system.

Navigating among the nodes is accomplished by triggering 'anchors' in the nodes which may be shown on the screen in various ways. Specially created icons or buttons may appear in the text or portions of the text which may be highlighted. When the anchor is activated, it connects the reader to a destination node in the same document or in another document entirely. As navigation can sometimes become difficult in larger hypertext accumulations, special navigation aids have been created to assist the user. These include maps of the hypertext showing nodes and paths, hierarchies showing lists of node titles, traces that show the track the user has made through the hypertext during the session, and so forth.

The important characteristics about hypertext that makes it an excellent learning environment is the ability of the student to move through a large body of textual information composed of multiple texts by following pre-planned sequences of links set into the text by the instructor. Research at Brown University at the Institute for Research in Information and Scholarship (IRIS) has indicated that links "condition the user to anticipate important and purposeful relationships between linked materials ... to stimulate and encourage habits of relational thinking in the user. This inherent emphasis upon interconnectedness provides a powerful means of teaching sophisticated critical "thinking" (Landow, 1989).

Educational Software Development Using Hypertext and Expert System Software Concepts

Hypertext applications include dictionaries (Raymond and Tompa, 1988), medical handbooks (Frisse, 1988), technical documents (Walker, 1987), and student advising (Malasri, 1990).

A HYPERTEXT EXAMPLE: WC-MIX

WC-MIX is a concrete mix design program using the water-cement-ratio method. The step-by-step explanation takes the students to six major steps in determining the concrete proportion, as shown in Figure 1. This can be used simply as a checklist for students who already know

```
..WC-MIX.....................................................
:                                                           :
: WATER-CEMENT-RATIO METHOD                                 :
: ------------------------                                  :
:   STEP-BY-STEP PROCEDURES:                                :
:                                                           :
:   <STEP 1> Determine air content (if needed)              :
:   <STEP 2> Determine w/c ratio                            :
:   <STEP 3> Determine slump                                :
:   <STEP 4> Perform trial mix                              :
:   <STEP 5> Determine unit weight of concrete              :
:   <STEP 6> Calculates mix proportion per cu.yd of concrete:
:                                                           :
:                                                           :
:                                                           :
:...........................................................:
.............................................................
: F1 Help      F3 Select                          Pg 1 of 1:
: Space Cont.  F4 View                F8 DOS     F10 Quit  :
:...........................................................:
```

Figure 1. Six major steps in determining a concrete mix.

how to determine the concrete proportion using this method. The symbol '< >' used in Figures are hypertext nodes, which imply that more information on those nodes is available upon request. In the actual system, these nodes are highlighted.

If the students would like to explore further, they can simply select a node of interest using function keys, F3 and F4, or using a pointing device, such as a mouse. For example, if the user selects the '**<STEP 2>**' node in Figure 1, more information is displayed in a window, as shown in Figure 2. Two more nodes, i.e., '**<exposure condition>**' and

```
..WC-MIX.....................................................
:                                                           :
: WATER-CEMENT-RATIO-METHOD                                 :
: --.....................................                   :
:   : The water-cement ratio (w/c) is determined:           :
:   : from the <exposure condition> and the     :           :
:   : <strength> of the concrete.               :           :
:   :                                           :           :
:   :                                           :           :
:   :                                           :           :
:   :                                           :           :
:   :.........................................:of concrete  :
:                                                           :
:                                                           :
:                                                           :
:                                                           :
:                                                           :
:...........................................................:
.............................................................
: F1 Help      F3 Select                          Pg 1 of 1:
: Space Cont.  F4 View                F8 DOS     F10 Quit  :
:...........................................................:
```

Figure 2. Window of deeper information.

'**<strength>**', appear for deeper information. If deeper information is requested, the system will overlay a new window over the existing ones, as shown in Figure 3. The system is also capable of displaying standard PCX graphics files. Figure 4 is displayed as a result of selecting the '**<typical graph>**' node on Figure 3.

The development of WC-MIX is facilitated by a software tool, KnowledgePro. The 'say' commmand is used to display messages. Windows are created using 'window()' and 'close_window()' commands. Hypertext links are marked with the '#m' command and nodes are provided through the 'topic' command. Graphics files are displayed with the 'picture' command. A partial list of WC-MIX source file is shown in Figure 5.

```
..WC-MIX.....................................................
:                                                           :
: WATER-CEMENT-RATIO-METHOD                                 :
: --.....................................                   :
:   : The water-cement ratio (w/c) is determined:           :
:   : f.....................................                :
:   : <:Water-cement ratio based on strength can  :         :
:   :  :be determined by:                         :         :
:   :  :  .....................................             :
:   :  :  :Established lab data can be obtained by  :       :
:   :  :  :several trial mixes with various w/c     :       :
:   :..:  :ratios. The 28-day strength of cylinder  :oncrete :
:      :  :from each mix is plotted versus w/c ratio:       :
:      :..:                                         :       :
:         :   * select here to see                  :       :
:         :     a <typical graph> *                 :       :
:         :.....................................:           :
:...........................................................:
.............................................................
: F1 Help      F3 Select                          Pg 1 of 1:
: Space Cont.  F4 View                F8 DOS     F10 Quit  :
:...........................................................:
```

Figure 3. Layers of windows for more depth information.

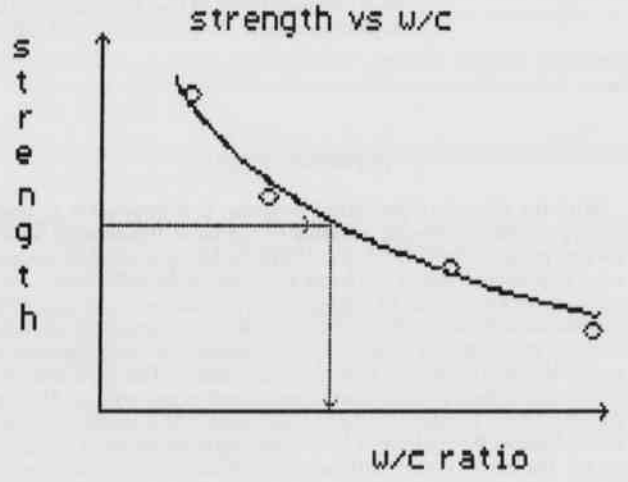

Figure 4. Capability of displaying PCX graphics files.

```
say(
' WATER-CEMENT-RATIO METHOD',
' ------------------------',
'   STEP-BY-STEP PROCEDURES:',
' ',
'   #mSTEP 1#m  Determine air content (if needed)',
'   #mSTEP 2#m  Determine w/c ratio ',
...
...
...
   topic 'STEP 2'.
   window().
   say(
   'The water-cement ratio (w/c) is determined',
   'from the #mexposure condition#m and the',
   '#mstrength#m of the concrete').
   close_window().
   end.
   ...
   ...
   ...
     topic 'typical graph'.
     picture (wc).
     end.
   ...
   ...
   ...
```

Figure 5. A partial list of WC-MIX source file.

WHAT IS EXPERT SYSTEM?

Expert systems are computer programs that use Artificial Intelligence (AI) techniques to make computer programs easier and more effective, and normally go beyond numerical programming into symbolic programming (Harmon and Sawyer, 1990). Expert systems are computer systems that employ human knowledge to solve problems that ordinarily require human intelligence (Hayes-Roth, 1990).

There are several ways human expertise can be represented in expert systems, such as rules, frames, objects. The IF-THEN rule is one of popular representations. Systems employ the IF-THEN rule representation known as 'Rule-Based Systems'. Since the example used in this work use the IF-THEN rules, discussion is therefore limited to rule-based systems.

Most rule-based systems have 3 separated components; the inference engine, knowledge bases, and explanation facilities. The inference engine is the part that solves problems by applying the knowledge in the knowledge bases. It determines which rules applied and in which sequence. Knowledge bases contain the domain knowledge. Due to the separation of knowledge bases from the inference engine, knowledge is transparent to the end-user. The student can clearly understand the knowledge in the system without having to understand a computer programming language. Knowledge bases are also easily debugged, modified and updated. The explanation facilities allow the student to probe the logic of the system, such as why the question is being asked or how the system reaches a conclusion. These educational benefits of rule-based systems will be demonstrated with a sample system, WCMXINFO, in the next section.

In recent years, the expert system development has been facilitated by the availability of development tools, known as 'shells'. A shell is simply an expert system with the inference engine, explanation facilities, and empty knowledge bases. The developer, using a shell, simply implements the knowledge bases. CBC-Xpert, one such shell, was developed at Christian Brothers University for educational purposes. Students can learn how to use the system quickly, due to its simplicity.

There have been several expert systems developed for uses in engineering education and several schools have offered courses on the subject as recently documented (Malasri *et al.*, 1990, Mohan and Maher, 1989).

Similar AI techniques used in expert systems have been used in more advanced systems known as Intelligent Tutoring Systems (ITS) or Intelligent Computer Assisted Instruction (ICAI). These systems try to find the misconception of the student and try to customize the tutoring material to the student (Barr and Feigenbaum, 1982). More recent research on ITS or ICAI is reported by Mandl and Lesgold (1988) and Wenger (1990).

AN EXPERT SYSTEM EXAMPLE: WCMXINFO

WCMXINFO contains information needed for the mix design calculation using the water-cement-ratio method. It addresses the same problem of WC-MIX, but with a different approach. The consultation begins with a menu from a main program written in BASIC, as shown in Figure 6. If the user selects the third option, the EXPOS.KBS knowledge base is used and the query starts, as shown in Figure 7. At this point, the user can ask WHY by typing "w". The system will respond by displaying the current rule, as shown in Figure 8. The system asks more questions until it reaches a conclusion as shown in Figure 9. The user can trace to see HOW the system reaches this conclusion. The system responds to the HOW question by displaying rules used in that particular consultation.

```
In the water-cement-ratio method of mix design,
you would need the information on the following
topics:

 1. air content
 2. average strength required
 3. w/c ratio based on exposure condition
 4. w/c ratio based on strength
 5. minimum cement for flatwork
 6. slump

 7. EXIT

Select an option ? _
```

Figure 6. Menu screen of WCMXINFO.

```
                    expos.kbs

What is the exposure condition?
     1    freeze-thaw cycles
     2    watertight
     3    frost-resistant
     4    sulfate attack
     5    placing concrete under water
     6    floors on grade
Enter the index of your response (1-6)> _
```

Figure 7. Consultation with EXPOS.KBS knowledge base.

```
                    expos.kbs

Why? Because "exposure_condition" is needed to evaluate
     rule 1.

Rule 1

IF    exposure_condition = "freeze-thaw cycles"
THEN  wc = "Select w/c ratio based on strength"
```

Figure 8. WHY question.

```
                    expos.kbs

                Results of database query

The maximum w/c ratio is --->  "0.50"
```

Figure 9. Conclusion screen.

The knowledge base can be easily developed using any wordprocessor capable of creating ASCII files. The listing of the EXPOS.KB knowledge base is shown in Figure 10. The 'title' command provides an identification for the knowledge base. The 'goal' command tells the system what to look for during the consultation. Once a value is found for the goal variable, the consultation terminates. The 'rules' section provides domain knowledge in the IF-THEN format. Rules can be in any order. Input data is obtained from messages specified in the 'prompts' section. The result of the consultation is displayed using the 'conclusion' command. There are only 5 commands used in the system with English-like syntax. Anyone, with or without the background on expert systems, can understand the knowledge which is explicitly built into the knowledge base.

In a typical expert system, the problem solving part or the inference engine is separated from the knowledge part. This makes the domain knowledge easy to check, to update, and to maintain. CBC-Xpert provides the develper with an inference engine (INFER.EXE). Knowledge bases are ASCII files created using any wordprocessor following a simple

```
title "expos.kbs"
goal wc
rules
1
if   exposure_condition = "freeze-thaw cycles"
then wc = "Select w/c ratio based on strength"
2
if   exposure_condition = "watertight"
and  water = "fresh water"
then wc = "0.50"
3
if   exposure_condition = "watertight"
and  water = "sea water"
then wc = "0.45"
4
if   exposure_condition = "frost-resistant"
and  member = "thin sections"
then wc = "0.45"
5
if   exposure_condition = "frost-resistant"
and  member = "all other sections"
then wc = "0.50"
6
if   exposure_condition = "sulfate attack"
and  sulfate = "moderate"
then wc = "0.50"
7
if   exposure_condition = "sulfate attack"
and  sulfate = "severe"
then wc = "0.45"
8
if   exposure_condition = "placing concrete under water"
then wc = "not less than 650 lb of cement per cu.yd."
9
if   exposure_condition = "floors on grade"
then wc = "select based on strength and minimum cement
          requirement"
prompts
exposure_condition
  "What is the exposure condition ?"
     "freeze-thaw cycles" "watertight" "frost-resistant"
     "sulfate attack" "placing concrete under water"
     "floors on grade" /
water
  "What is the type of water ?"
     "fresh water"  "sea water" /
member
  "What is the type of member ?"
     "thin sections"  "all other sections" /
sulfate
  "What is the level of sulfate attack ?"
     "moderate" "severe" /
conclusion
"The maximum w/c ratio is ---> " wc
```

Figure 10. The listing of the EXPOS.KB knowledge base.

syntax. The consultation is made by executing the inference engine with proper knowledge base, such as:

> INFER AIR.KBS

In WCMXINFO, a main program was written in BASIC to provide a menu, as shown in Figure 6, and bring up the appropriate knowledge base, as shown in Figures 7-9. The CBC-Xpert's inference engine is called with an appropriate knowledge base using the 'SHELL' command in BASIC, as shown in Figure 11.

```
...
...
390  INPUT "        Select an option ";N
400  IF N=1 THEN  SHELL "infer.exe  air.kbs"
410  IF N=2 THEN  SHELL "infer.exe  avgstr.kbs"
420  IF N=3 THEN  SHELL "infer.exe  expos.kbs"
430  IF N=4 THEN  SHELL "infer.exe  wc.kbs"
440  IF N=5 THEN  SHELL "infer.exe  flatwk.kbs"
450  IF N=6 THEN  SHELL "infer.exe  slump.kbs"
460  IF N=7 THEN  SYSTEM
...
...
```

Figure 11. The SHELL command in the main program.

CONCLUSION

Hypertext is an alternative information system that offers the students a completely interactive encounter with the topics of study, permitting them to stretch their growth potential by providing multiple levels of increasing technicality. When combined with Expert Systems, a "glass box" feature is provided to the structure of the knowledge and logic contained in the system. With tools such as KnowledgePro and CBC-Xpert, the creation of such alternative information systems and updating of materials can be easily accomplished by non-programmers. We are tempted to say that this alternative system renders traditional textbooks obsolete as complex knowledge can be packaged and delivered electronically, as well as easily revised, delivered and stored. Besides learning the course contents, students are given increased skill with relational and critical thinking, as well as exposed to new training technologies that they will see with increasing frequency.

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FECUNDITY OF MALE WHITE-TAILED DEER ON HOLLA BEND NATIONAL WILDLIFE REFUGE

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ABSTRACT

Male reproductive tracts were collected from 57 white-tailed deer *(Odocoileus virginianus)* harvested on Holla Bend National Wildlife Refuge during the 1988 and 1989 archery deer seasons. Organ weights and total numbers of spermatozoa present were determined for both testes and epididymides. Among yearling and adult males, the mean weights of testes and epididymides peaked during November and decreased through the end of the collection period in mid-December. Total number of spermatozoa in the tract increased through October, peaked during the last half of November, and decreased through mid-December. No significant difference was found between the mean number of spermatozoa in the tracts of yearling (1.5 years old) and adult ≥ 2.5 years old) males ($p = 0.48$). Testicular spermatozoa numbers ($\times 10^9$) averaged 2.9 ± 0.5 S.E. and 3.7 ± 0.6 S.E. for yearlings and adults, respectively. The mean number ($\times 10^9$) of spermatozoa in the epididymides averaged 8.6 ± 1.1 S.E. and 9.8 ± 1.3 S.E. for yearlings and adults. No spermatozoa were found in the epididymides of 19 fawns sampled. However, low numbers of spermatozoa were present in the testes of 3 (16%) fawns.

INTRODUCTION

The white-tailed deer *(Odocoileus virginianus)* is of special interest to wildlife biologists and hunters in Arkansas due to its economic and ecologic value. It is also one of the few game animals harvested during its breeding season. Because mature males are preferentially sought by most hunters, and these deer are very active during the rut, they are particularly vulnerable to harvest (Roseberry and Klimstra, 1974). Presumably the timing of the deer season relative to the rut could impact the reproductive performance of a deer population by excessive removal of males when hunting pressure is high.

Relatively few efforts have been made to delineate the timing or magnitude of spermatogenesis among deer, or to assess differences in the fecundity of males related to age (Payne *et al.*, 1966; Lambiase *et al.*, 1972; Mirarchi *et al.*, 1977). This study was undertaken to determine when the peak of spermatogenesis among mature males occurs, if yearling males produce as many spermatozoa as older deer, and if male fawns in Arkansas undergo spermatogenesis.

MATERIALS AND METHODS

Complete reproductive tracts were collected from 57 male deer harvested on Holla Bend N.W.R. during the 1988 and 1989 archery deer seasons. The archery season on the refuge extended from 1 October through 15 December both years. Dressed body weights and age (estimated by tooth replacement and wear) were recorded for each deer at the deer check station on Holla Bend (Severinghaus, 1949). Reproductive tracts were immediately frozen and returned to Arkansas Tech University for further processing.

Testes and epididymides were removed from the scrotum, separated, trimmed of extraneous materials, and weighed. Each paired organ was then minced, and homogenized in 200 ml of normal saline solution in a blender (Almquist and Amann, 1961). Each suspension was diluted and stained for 8-12 hours with rose bengal to facilitate the counting of spermatozoa. Spermatozoa were counted using a hemacytometer and light microscope. Spermatozoan numbers were expressed as number per organ pair.

Means were calculated separately for paired testicular weights and spermatozoan numbers, and for paired epididymal weights and spermatozoan numbers. Temporal changes in organ weights and numbers of spermatozoa were graphed by grouping data for deer harvested during each half of each month. Differences between the reproductive performance of yearlings and older males were tested using T-tests. The relationship between the total weight of the reproductive tract and numbers of spermatozoa was assessed using the Pearson product-moment correlation. Both tests were conducted at the 0.05 alpha-level using the SAS statistical package (Barr and Goodnight, 1971).

RESULTS AND DISCUSSION

TIMING OF SPERMATOGENESIS

The period of peak spermatogenesis was estimated based on temporal changes in organ weights and numbers of spermatozoa in testes and epididymides. Mean weights of testes and epididymides generally increased through October, peaked in November, and decreased slightly through early December (Fig. 1). Mirarchi *et al.* (1977) reported that testicular weights peaked in October, and epididymal weights peaked in November in deer sampled in Virginia.

All yearlings and adults harvested on Holla Bend during early October had spermatozoa present in both the testes and epididymides (Fig. 1). This suggests that spermatogenesis was initiated prior to the beginning of archery season in virtually all antlered males. Significant numbers of sperm in the reproductive tract have been reported to occur as early as July in Virginia and August in Pennsylvania (Lambiase *et al.*, 1972; Mirarchi *et al.*, 1977). On Holla Bend, peak numbers of spermatozoa occurred in both the testes and epididymides during November, with numbers declining somewhat during the first half of December (Fig. 2). Similar patterns have been reported from Pennsylvania and Virginia (Lambiase *et al.* 1972, Mirarchi *et al.* 1977).

TESTICULAR GROWTH AND SPERM RESERVES

The mean weight of fawn testes was lower than that of yearlings ($P < 0.01$), however no difference was found between testicular weights of yearlings and older deer ($P < 0.07$). Mean weights (g) for paired testes were 6.9 ± 0.7, 41.7 ± 2.2, and 49.3 ± 3.8 for fawns, yearlings, and adults, respectively.

Similarly, epididymal weights were lower in fawns than in yearlings ($p < 0.01$). Yearlings and adults did not differ ($p < 0.08$). Epididymal weights (g) averaged 4.4 ± 0.3, 14.3 ± 0.9, and 16.6 ± 0.9 for fawns, yearlings, and adults.

Testicular weights recorded during this study are lower than those reported from northern states (Cheatum and Morton, 1946; Lambiase *et al.*, 1972), but are comparable to weights reported for deer from central Texas (Robinson *et al.*, 1965). These differences are probably attributable to differences in body size between northern and southern deer populations.

Fecundity of Male White-Tailed Deer on Holla Bend National Wildlife Refuge

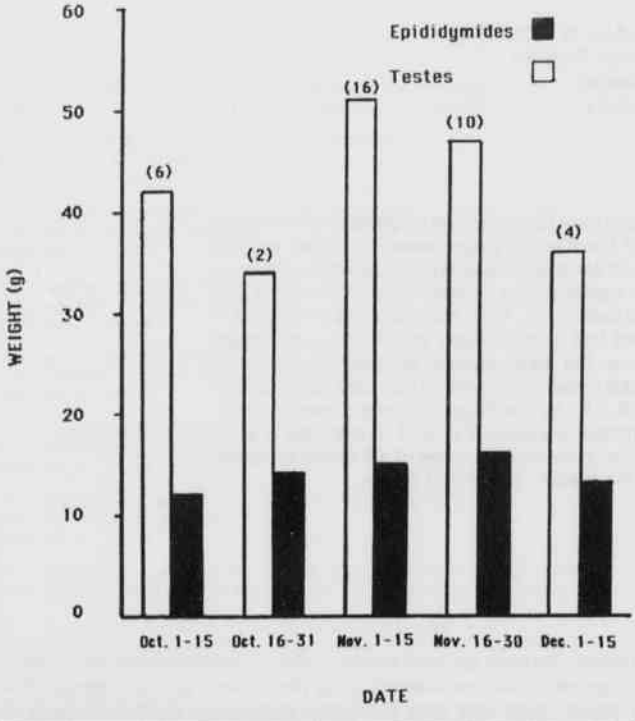

Figure 1. Mean weights of paired testes and epidiymides from yearling and older-age deer harvested during each 2-week period in 1988 and 1989 on Holla Bend N.W.R. Numbers in parentheses indicate sample size.

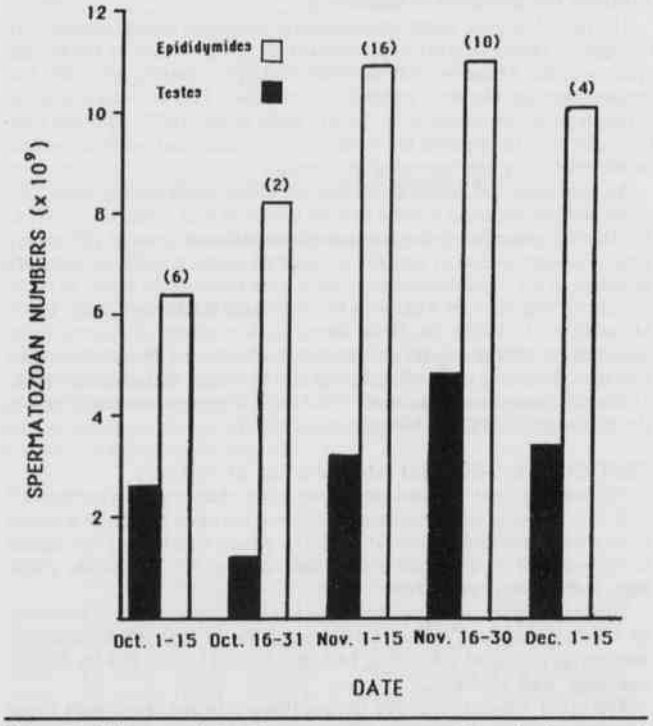

Figure 2. Mean numbers of spermatozoa present in paired testes and epidiymides from yearling and older-age deer harvested in each 2-week period on Holla Bend N.W.R., 1988 and 1989. Numbers in parentheses indicate sample size.

Epididymal weights apparently vary less with season and geographic location. Weights recorded in this study are very similar to those from deer in Pennsylvania and Virginia (Lambiase *et al.*, 1972; Mirarchi *et al.*, 1977).

Yearlings did not differ from adults in the mean number of spermatozoa present in the testes ($p < 0.28$) or epididymides ($p < 0.48$). Yearlings averaged 8.6 ± 1.1 billion spermatozoa in the epididymides, and 2.9 ± 0.5 billion in the testes. Adults averaged 9.8 ± 1.3 billion spermatozoa in the epididymides, and 3.7 ± 0.6 billion in the testes. Lambiase *et al.* (1972) reported sperm reserves in yearlings comparable to those in older males, but noted that this result might have been due to small sample size ($N = 10$). Our results, with a larger sample, support their data.

Sperm reserves and weights of male reproductive organs have been shown to follow a distinct annual cycle in deer (Lambiase *et al.*, 1972). These values are generally lowest from February through June, increase through summer and fall, and peak during October and November. Although the period of collection during this study was limited to 10-weeks (from 1 October through 15 December), this was the peak period of spermatogenesis and breeding. A significant correlation ($r = 0.74$, $P < 0.001$) existed between the combined weight of testes and epididymides and total sperm reserves, suggesting that the increase in organ weights recorded through October and nearly November corresponded to increased spermatogenic activity (Mirarchi *et al.*, 1977).

SEXUAL MATURITY OF MALE FAWNS

Of 19 male fawns sampled, none were found to have spermatozoa present in the epididymides. However, low numbers of spermatozoa ($\bar{X} = 5 \times 10^7$) were found in the testes of 3 (16%) fawns. Sexually mature fawns tended to be heavier (36.0 ± 4.0 kg) than immature males (26.6 ± 1.5 kg); however, the difference was not statistically significant ($P < 0.17$). None of the mature fawns weighed less than 30 kg, although several fawns exceeding 35 kg were sexually immature.

While Cheatum and Morton (1946) found no evidence of fertility among male fawns in New York, Lenker and Scanlon (1973) found that 25% of this class produced spermatozoa in Virginia. Mean weights of mature and immature fawns in the latter study corresponded very closely to those reported above. Follman and Klimstra (1969) reported that 36.9% of male fawns collected during January in southern Illinois were fertile. Fertility was found to be a function of weight, and inferentially of age in the latter study.

Behavioral studies of white-tailed deer have indicated that dominant adult males are responsible for the vast majority of breeding under normal circumstances (Hirth, 1977; Ozoga and Verme, 1985). Subordinate male fawns and yearlings are usually prevented from breeding by these dominant individuals. This is likely the case among most deer populations throughout Arkansas. However, Ozoga and Verme (1985) also reported that there was no decrease in the reproductive performance of captive females when adult males were experimentally removed, and only yearling males were left to breed. They noted that yearlings exhibited age-related differences in rutting behavior, and that less stable dominance hierarchies may have resulted from the absence of older males. Nevertheless, yearlings were capable of successfully impregnating most receptive does when dominant males were removed. Our data indicate that yearling males in Arkansas produce sufficient sperm reserves to maintain herd productivity in the absence of older males.

ACKNOWLEDGMENT

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SOIL AND LITHOSTRATIGRAPHY BELOW THE LOVELAND/SICILY ISLAND SILT, CROWLEY'S RIDGE, ARKANSAS

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ABSTRACT

Two stratigraphic units between the Loveland/Sicily Island Silt and the Pliocene sand and gravel on Crowley's Ridge were analyzed to determine their origin and assess the degree of pedogenic development. The Crowley's Ridge Loess, the upper unit, was up to 2.6 m thick, was not laterally continuous, and contained a well developed paleosol. The lower unit was a several meter thick sandy facies of the Pliocene sand and gravel which contained a weak paleosol. Particle size analysis revealed that the upper unit exhibited texture similar to the overlying loess units, with unimodal silt comprising greater than 95% of the clay-free material. The lower unit has a bimodal distribution with modes of medium sand and coarse silt, that is bedded and cross-bedded below the pedogenic horizons. Thin sections of pedogenic horizons in both units revealed clay films that are strongly oriented and abundant in the B horizons with most voids occurring in the AB horizons. In conclusion, there are four loess units on Crowley's Ridge. A significant period of weathering followed deposition of the oldest widespread loess with at least a short period of weathering following the deposition of the sandy Pliocene alluvium.

INTRODUCTION

Crowley's Ridge is a unique landform that rises as much as 60 m above the surrounding terrain. This narrow erosional remnant trends north-south from southeastern Missouri to east central Arkansas, extending approximately 300 km (Fig. 1). It formed as a divide between the ancestral Mississippi River to the west and the Ohio River to the east. The two rivers eroded unconsolidated coastal plain sediments forming broad alluvial valleys (Call, 1891). It is widely recognized that the ridge is comprised of unconsolidated Eocene clastics overlain by Pliocene sand and gravel. Historically, these units have been considered to be overlain by three layers of Pleistocene loess; the Loveland/Sicily Island Silt being the oldest, succeeded by the Roxana Silt, and the youngest, Peoria Loess (West *et al.*, 1980; Guccione *et al.*, 1986).

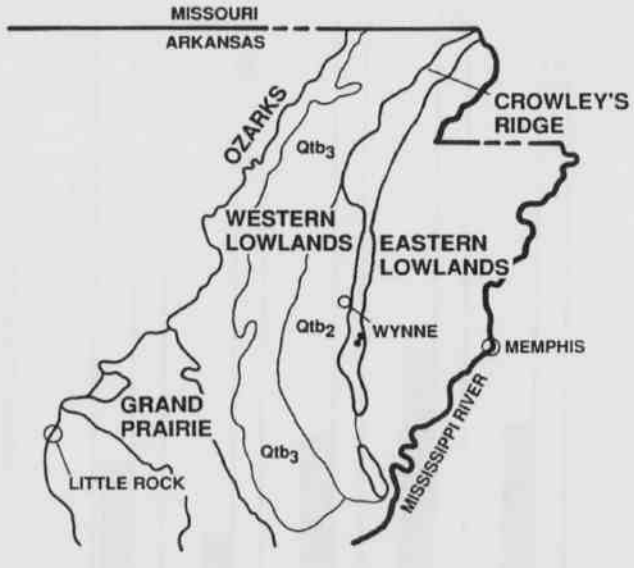

Figure 1. Location map of Crowley's Ridge and selected geomorphic regions of Northeast Arkansas. Study sites at Wittsburg Quarry and Village Creek landslide are shown by squares. Taken from Rutledge *et al.*, (1990).

However, there are 2 stratigraphic units between the Loveland/Sicily Island Silt and Pliocene sand and gravel that have not been well recognized. The purpose of this study was to describe these units, determine their mode of deposition, and assess the degree of pedogenic development within each unit. The upper unit, the Crowley's Ridge Loess, has been correlated with loesses in Louisiana (Rutledge *et al.*, 1990; Miller *et al.*, 1986). The lower unit has not been named or correlated, but for the purpose of this paper will be referred to as Pliocene sand.

The units are well exposed at multiple localities near Wynne, Arkansas in Cross County (Fig. 1). The deposits and their soil profiles were described and sampled on the south face of the Wittsburg Quarry and at Village Creek State Park. At both of these locations, the Crowley's Ridge Loess pinches out laterally (Fig. 2). The units have also been recognized at the nearby Bledsoe Section by Rutledge *et al.*, (1990).

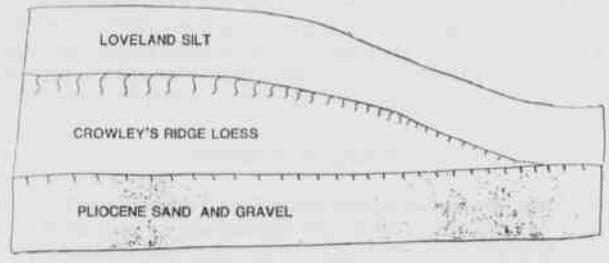

Figure 2. Diagramatic cross section of a selected portion of the north-facing wall, Wittsburg Quarry.

METHODS

The sediment and soil profiles were described using the standard

USDA format (Soil Survey Staff, 1981). Two samples were taken from the base of the overlying Loveland Silt, and 7 samples each from the Crowley's Ridge Loess and the Pliocene sand. These samples were analyzed for grain size. Gravel and sand fractions were dry sieved and weighed. Silt and clay fractions were analyzed by the pipette method (Day, 1965). Gravel is reported as a percent of the total sample and is >2 mm. Sand is reported as a percent of the clay-free (0.002-2 mm) fraction to eliminate the effect of pedogenesis. Silt is the 0.0625 mm to 2 micron fraction, and clay is <2 microns.

Seven samples were taken for thin section examination. One from the Loveland/Sicily Island Silt, and 3 each from the Crowley's Ridge Loess and the Pliocene sand. Each thin section analysis included 230 to 260 point counts and the terminology of Brewer (1964) was used in describing micromorphology. The term cutan is defined as a modifcation of the texture, structure, or fabric at natural surfaces in soil materials due to concentrations of particular soil constituents or in situ modification of the plasma. Cutans include argillans or clay films, and other ped coatings. The term glaebule includes nodules and concretions. It is defined as a three dimensional unit within the S-matrix of the soil material and is usually prolate to equant in shape. It is recognized as a unit either because of a greater concentration of some constituent and/or a difference in fabric compared with the enclosing soil material, or because it has a distinct boundary with the enclosing soil material. S-matrix is defined as the material within the simplest primary ped in which the pedologic features occur.

SEDIMENT

The Loveland/Sicily Island Silt is approximately 8.6 m thick at the Wittsburg Quarry (Guccione *et al.*, 1986). It was sampled because it was considered to be a loess and could be used for comparison with the underlying units being examined in this study. The upper sample was taken from the C horizon 90 cm above the base of the Loveland/Sicily Island Silt. The second sample was taken 5 cm from the base. These samples are typical of the Loveland/Sicily Island Silt in the area (West *et al.*, 1980). They are unimodal deposits with a coarse silt mode. On a clay-free basis, silt makes up greater than 95% of the sample (Table 1). West *et al.*, (1980) concluded that the relatively coarse grain size of the Loveland/Sicily Island Silt was due to a source close to the site of deposition.

Table 1. Size analysis of samples taken from profile at Wittsburg Quarry; 2 mm to 2 microns. Reported on a clay-free basis to eliminate the effect of pedogenesis.

Horizon	Horizon Depth (cm)	Sample Depth (cm)	% Sand						% Silt			
			VC	C	M	F	VF	Total	C	M	F	Total
C		-90	0	0	0	0	0	1	77	22	0	99
C		-5	0	0	1	1	1	2	70	23	4	98
ABt	0- 79	13	0	0	0	0	0	1	69	28	3	99
Bt	79-149	73	0	0	0	1	1	2	66	28	4	98
Bt	79-149	102	0	0	0	0	1	1	70	25	5	99
BC	149-185	169	0	0	0	0	0	1	69	26	4	99
C	185-225	213	0	1	4	1	1	7	64	25	4	93
C	225-256	232	0	2	10	4	3	19	55	24	2	81
2A	256-274	259	1	4	16	6	4	31	45	21	3	69
2ABt	274-309	279	3	5	18	6	4	36	42	18	3	64
2ABt	274-309	298	2	5	22	8	6	44	35	19	3	56
2Bt	309-368	315	2	6	21	8	6	43	39	15	2	57
2Bt	309-368	331	3	6	24	9	7	48	32	17	4	52
2Bt	309-368	352	2	8	30	10	9	59	27	11	3	41
2BCt	368-386	379	8	15	43	9	7	81	11	7	1	19

The Crowley's Ridge Loess has a maximum thickness of 2.4 m in the Wittsburg Quarry. The first 6 samples taken 13-213 cm below the upper contact are unimodal with a coarse silt mode. On a clay-free basis, silt makes up 93-99% of the samples. The seventh sample from the Crowley's Ridge Loess was taken 20 cm above the base of the deposit. On a clay-free basis, the percentage of sand was more than double compared to that in the overlying sample, and the silt fraction decreased to 81% (Fig. 3). This sample is interpreted as transitional between the

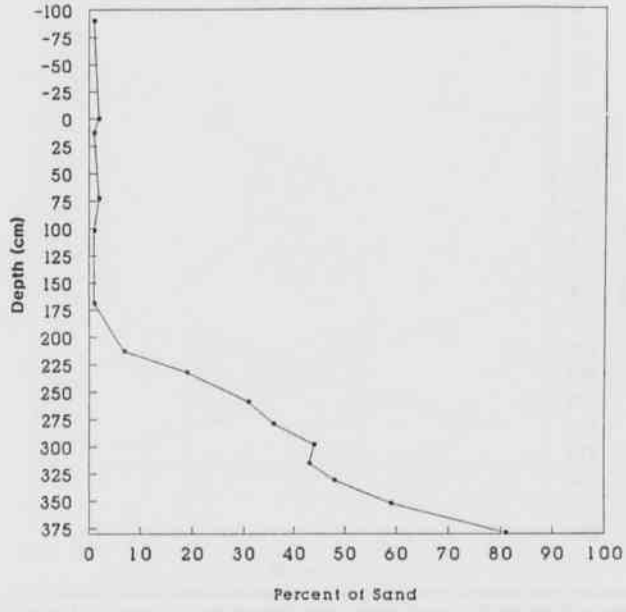

Figure 3. Percent of sand versus depth (cm). Samples were taken from Wittsburg Quarry. The contact between Loveland/Sicily Island Silt and Crowley's Ridge Loess is at zero cm. The contact between Crowley's Ridge Loess and Pliocene sand is at 256 cm.

Crowley's Ridge Loess and the underlying Pliocene sand. Probably mixing between these two units has occurred in this transition zone.

In the field there was a significant change in lithology, pedology, and weathering characteristics between the Crowley's Ridge Loess and the Pliocene sand. The Pliocene sand was 130 cm thick. The grain size distribution on a clay-free basis was bimodal with modes in the medium sand and coarse silt fractions (Table 1), and the percent of sand increased with depth. Total sand fraction increases from 7% of the sand plus silt fractions in the upper part of the unit to 81% at the base of the Pliocene sand.

The same units were also examined approximately 8 km (5 mi) southwest of the Wittsburg Quarry at the Village Creek landslide. The deposits were similar to those at Wittsburg Quarry (Fig. 4).

SOIL

The Loveland/Sicily Island Silt, the Crowley's Ridge Loess and the Pliocene sand were described in the field, examined in thin sections, and the grain size was quantified in the laboratory to determine if buried soils were present. The lower 90 cm of the Loveland/Sicily Island Silt was examined for comparison with the underlying units. The C horizon of the Loveland/Sicily Island is a massive, yellowish brown, silty horizon with at least 10% clay (Table 2). The lower 30 cm of the deposit is a transition zone. It contains a greater amount of clay (33%) than the unmodified loess. A thin section of a sample from the transition zone contained feldspar, mica, and secondary calcite in addition to the abundant quartz grains.

A strong paleosol was developed in the Crowley's Ridge Loess, which was less developed laterally as the loess unit pinches out. Field observations of the upper 79 cm suggested that this is an ABt horizon (Table 3). It is a yellowish brown/strong brown silty clay, with distinct yellowish red clay films. In thin section, void content was 13% compared to 4% in the above C horizon (Fig. 5). A high percentage of non-planar voids indicated the presence of root pores and/or burrows, characteristics

Soil and Lithostratigraphy Below the Loveland/Sicily Island Silt, Crowley's Ridge, Arkansas

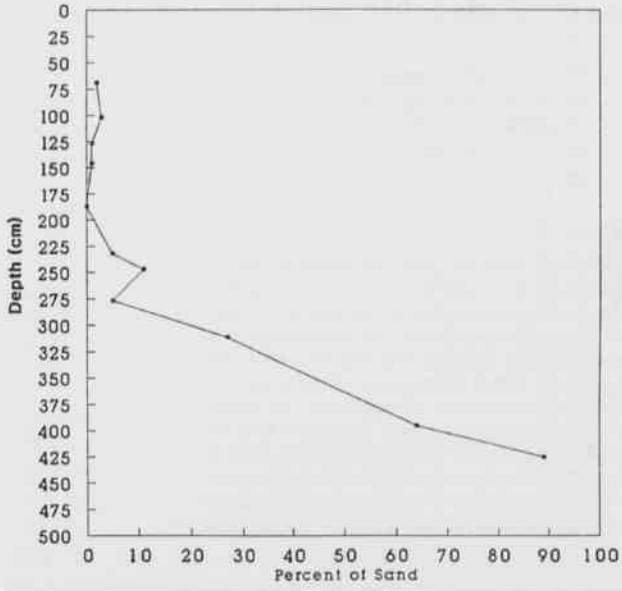

Figure 4. Percent of sand versus depth (cm). Samples were taken from Village Creek landslide. The contact between Loveland/Sicily Island Silt and Crowley's Ridge Loess is at approximately 80 cm. The contact between Crowley's Ridge Loess and Pliocene sand is at 235 cm.

Table 2. Size analysis of samples taken from profile at Wittsburg Quarry. Includes a percent of the < 2 micron fraction to assess the effect of pedogenesis.

Horizon	Horizon Depth (cm)	Sample Depth (cm)	% Total Gravel	% Sand VC	C	M	F	VF	Total	% Silt C	M	F	Total	% Clay
C		-90	0	0	0	0	0	0	0	70	20	0	90	10
C		-5	0	0	0	1	0	1	2	48	16	3	66	33
ABt	0- 79	13	0	0	0	0	0	0	0	41	17	2	59	41
Bt	79-149	73	0	0	0	0	0	1	1	41	17	3	61	38
Bt	79-149	102	0	0	0	0	0	1	1	46	16	3	65	34
BC	149-185	169	0	0	0	0	0	0	0	53	20	3	76	24
C	185-225	213	0	0	1	3	1	1	5	47	19	3	68	27
C	225-256	232	1	0	2	7	3	3	14	40	17	1	58	28
2A	256-274	259	0	1	3	12	4	3	23	34	16	3	52	25
2ABt	274-309	279	1	2	4	14	5	3	29	34	15	3	52	19
2ABt	274-309	298	1	1	4	17	6	4	32	26	14	2	42	26
2Bt	309-368	315	1	2	4	15	5	4	30	27	10	2	39	31
2Bt	309-368	331	1	2	4	15	6	4	30	20	10	2	33	37
2Bt	309-368	352	2	1	5	19	6	6	38	18	7	2	27	35
2BCt	368-386	379	6	5	11	31	6	5	58	8	5	1	13	28

associated with an A horizon. Planar voids were also more abundant in this horizon due to stronger soil structure. Cutans increased to 22% relative to 4% in the above C horizon (Fig. 6). This increase in cutans was consistent with the increase in clay content which reached a maximum of 41% in the underlying ABt horizon (Fig. 7). The Bt horizon was 70 cm thick; structure was weaker, and clay content decreased to 34%. Clay films were common but thin, decreasing in abundance toward the base of the horizon.

The lowest pedogenic horizon in the Crowley's Ridge Loess has been classified as a BC horizon due to the continued presence of thin clay films. Structure was massive throughout the BC and C horizons. In thin section, the transitional C horizon, 20 cm from the base of the loess, contained weakly developed cutans within vesicles and along planar voids (Fig. 8).

Table 3. Soil Description of the Wittsburg Quarry

HORIZON DEPTH (cm)	THICKNESS (cm)	HORIZON	COLOR	TEXTURE	STRUCTURE	SPECIAL CHARACTERISTICS
-90		C1	10YR 5/4 Yellow brown.	Silt	Massive	Loveland Silt
-5		C2	10YR 5/4 Yellow brown with 10YR 5/8 yellow brown mottles.	Silty clay loam	Massive	Transition zone
0-79	79	ABtb	10YR 5/4 Yellow brown with abundant 5YR 5/6 yellow red and 7.5YR 5/8 strong brown mottles.	Silty clay	Moderate medium subangular blocky	Manganese stains lining root pores/worm burrows. Clay films common to many at base.
79-149	70	Btb	10YR 5/6 Yellow brown and 10YR 6/8 brown yellow.	Silty clay loam	Weak medium subangular blocky	Clay films common, thin; becoming few, thin towards base.
149-185	36	BCb	10YR 5/8 Yellow brown with 10YR 7/3 pale brown along vertical joints.	Silt loam	Massive	Few, thin clay films.
185-225	40	Cb1	10YR 5/8 Yellow brown with 10YR 7/3 very pale brown mottles.	Silty clay loam	Massive	No clay films.
225-256	31	Cb2	10YR 5/8 Yellow brown.	Silty clay loam	Massive	Transition zone
256-274	18	2ABb	10YR 5/8 Yellow brown.	Silt loam	Weak medium subangular blocky	Abundant root pores.
274-309	35	2ABtb	7.5YR 5/6 Strong brown.	Loam	Moderate medium subangular blocky	Scattered pebbles. Common root pores. Common to many clay films.
309-368	59	2Btb	7.5YR 5/6 Strong brown with 5YR 4/4 reddish brown mottles at base.	Clay loam	Moderate medium subangular blocky	Scattered pebbles. Common distinct clay films.
368-386	18	2BCb	7.5YR 5/6 Strong brown with many coarse 2.5YR 4/6 red mottles.	Sandy clay loam	Weak fine subangular blocky to massive towards base	Many scattered pebbles. Few thin clay films.

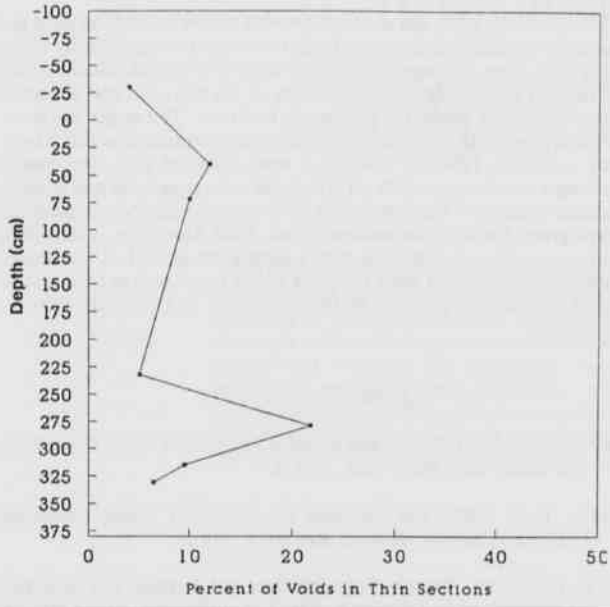

Figure 5. Percent of voids in thin section versus depth (cm) at Wittsburg Quarry. Contact between Loveland/Sicily Island Silt and Crowley's Ridge Loess is at zero cm. Contact between Crowley's Ridge Loess and Pliocene sand is at 256 cm.

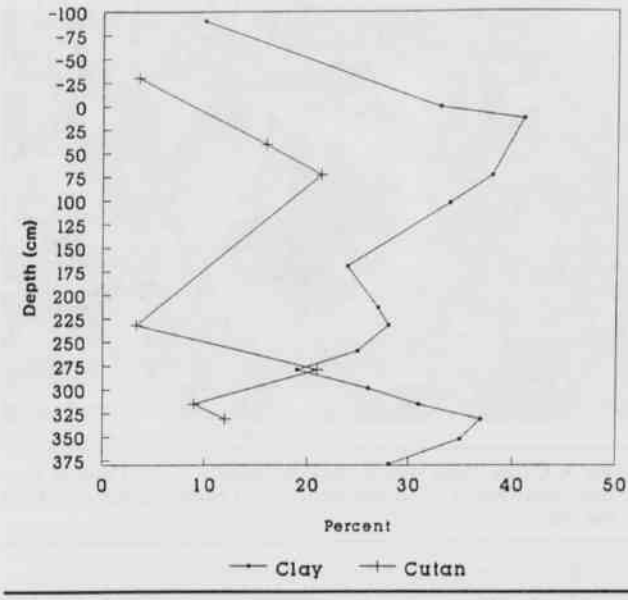

Figure 7. Percent of clay/cutans versus depth (cm) at Wittsburg Quarry. Cutan data is from thin sections. Clay data is from size analysis of the < 2 micron fraction. Contact between Loveland/Sicily Island Silt and Crowley's Ridge Loess is at zero cm. Contact between Crowley's Ridge Loess and Pliocene sand is at 256 cm.

Figure 6. Cutans lining planar void in the ABt horizon of the Crowley's Ridge Loess at Wittsburg Quarry. This feature is 60 cm below the upper contact of the unit.

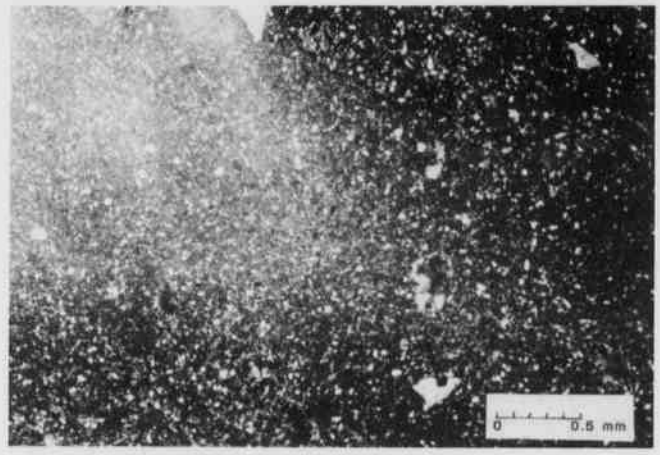

Figure 8. Massive structure in the C horizon of the Crowley's Ridge Loess at Wittsburg Quarry.

A weak paleosol was developed in the Pliocene sand. Field observations of the upper 18 cm suggested that this is an A horizon (Table 3). The horizon contained a few light gray mottles and pores were common. Structure graded to moderate medium angular blocky in the underlying strong brown loam of the ABt horizon. Clay films were common to many and distinct. In thin section, cutans increased from 3% in the overlying C horizon of the Crowley's Ridge Loess to 21% in the ABt horizon (Fig. 7). Voids increased from 4% in the overlying C horizon to 22% in the ABt (Fig. 9).

Clay increased to a maximum of 37% in the Bt horizon (Fig.7). This was a strong brown clay loam with many distinct yellowish red and very pale brown mottles. Common, distinct clay films were observed in the field. The 2 thin sections from this horizon exhibited fewer voids than in the overlying A horizon (Figure 5). Cutans decreased from 21% in the overlying ABt horizon to 9-12% in the Bt horizon (Figure 7). In the A horizon, the cutans lined abundant voids. However, in the B horizon, the cutans lined the planar voids or ped faces. Sesquioxide and manganiferous glaebules noted in thin section corresponded with the megascopic presence of red mottles. The lower horizon, a BC, was a strong brown sandy clay loam with many coarse red mottles. A few thin clay films were observed. The boundary with the underlying gravel was abrupt.

Soils developed in the Crowley's Ridge Loess and Pliocene sand at the Village Creek Landslide were less developed than those at the Wittsburg Quarry. The percent of clay only reached a maximum of 24% in the Crowley's Ridge Loess and 8% in the Pliocene sand (Figure 10). The weaker soil development may be due to higher erosion rates at this site.

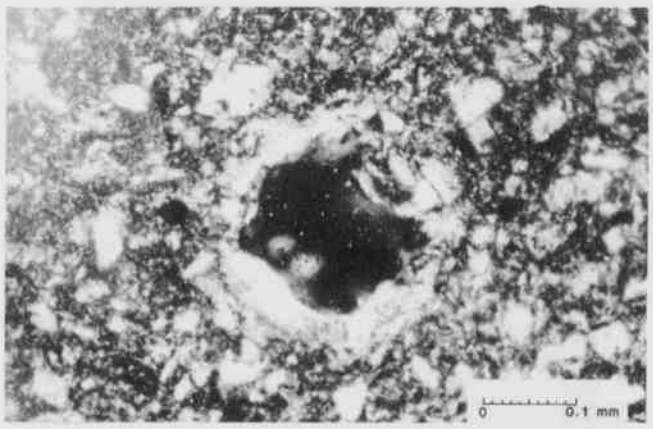

Figure 9. Cutan lining void in the ABt horizon of the Pliocene sand at Wittsburg Quarry. This feature is 27 cm below the upper contact of the unit.

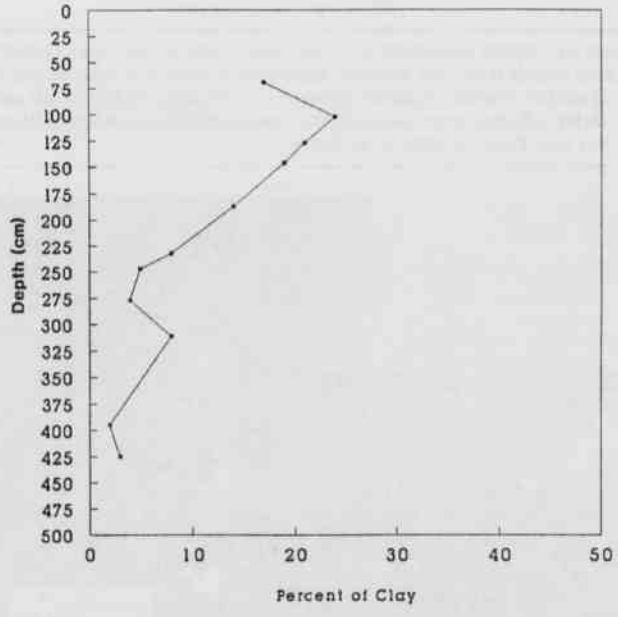

Figure 10. Percent of clay versus depth (cm) at Village Creek landslide. Clay data is from size analysis of the < 2 micron fraction. Contact between Loveland/Sicily Island Silt and Crowley's Ridge Loess is approximately 80 cm. Contact between Crowley's Ridge Loess and Pliocene sand is at 235 cm.

CONCLUSION

The unimodal silt, similar in grain size and topographic position to the Loveland/Sicily Island Silt is loess and as a result, 4 loess units have been identified on Crowley's Ridge. Soil development is significant with clay content reaching a maximum of 41% in this unit. Based on other studies done on the ridge (Rutledge *et al.*, 1990), we have designated this unit to be the Crowley's Ridge Loess.

The biomodal grain size distribution with modes in medium sand and coarse silt indicate that the second unit below the Loveland/Sicily Island Silt is not a loess, but more likely is of an alluvial origin. Medium sand increases in abundance toward the base of the alluvium and is bedded and crossbedded below the pedogenic horizons. The upper horizons, silt loam grading to clay loam, may have been deposited as distal overbank sediment. This unit contains a weak paleosol with clay content reaching a maximum of 37%. It is thought to be preglacial and possibly Pliocene because of the dominance of chert and scarcity or absence of erratic grains found in the sediment (Call, 1889; Guccione, *et al.*, 1986).

Consequently, we conclude that a significant period of weathering followed deposition of the Crowley's Ridge Loess and at least a short period of weathering followed the deposition of the sandy Pliocene alluvium.

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SCREENING RICE (*ORYZA SATIVA* L.) GENOTYPES FOR DROUGHT TOLERANCE UNDER FIELD CONDITIONS

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ABSTRACT

We evaluated the root pulling resistance (RPR) technique developed at the International Rice Research Institute (IRRI) for transplanted rice (*Oryza sativa* L.) to determine its applicability for assessing the drought tolerance of direct seeded rice. Experiments were conducted in 1988 and 1989 at the University of Arkansas at Pine Bluff Agricultural Research Farm. Fifty genotypes from four countries were grown with and without irrigation. The genotypes identified as drought tolerant germplasm by the RPR method in both years were significantly correlated. In both 1988 and 1989, RPR was directly related to maximum root length, root number, and root dry weight. Root dry weight (RWT) had the highest correlation with RPR in both 1988 ($r = 0.82^{**}$) and 1989 ($r = 0.46^{**}$). Cultivars with the greatest root lengths and root dry weights had the highest root pulling resistances.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for the majority of the world. Rice consumption in the U.S.A. increased from 2.5 million tons in 1980 to 3.6 million tons in 1989. The U.S. rice crop is flood irrigated and supplies about 19% of the world rice trade (USDA, 1989).

Arkansas is the leading rice producing state in the U.S. with about 42% of the total production in 1989 (Arkansas Agricultural Statistics Service, 1990). All Arkansas rice is grown under irrigated conditions. Approximately 70 to 90 ha-cm of irrigation water is required for rice during the growing season (Arkansas Cooperative Extension Service, 1982). Underground water levels are dropping in some irrigated regions, and salinity, alkalinity, sodicity, and Zn-deficiency are likely to occur in some areas, posing a threat to crop production (Gilmour, 1989). Two actions to help alleviate the problem are to reduce the use of irrigation water by developing rice germplasm with increased water-use efficiency and to make better use of surface (runoff) water. Arkansas rice growing areas receive about 50 to 60 cm of rainfall during the growing season (April through October). A drought tolerant cultivar or one with increased water-use efficiency would reduce the need for water.

Rice is grown under a wide range of conditions throughout the world. A broad spectrum of cultivars and land races with varying degrees of adaptation to water stress are present within currently available rice germplasm. Drought tolerance in rice can minimize the high irrigation requirements and contribute to water use efficiency. Rice plants avoid water stress, to a great extent, by developing more extensive and deeper root systems, which can be measured by root pulling resistance (RPR).

Research at the International Rice Research Institute (IRRI) demonstrated that a highly developed root system was the most important mechanism needed to maintain an adequate flow of water to the canopy during extended dry periods (Steponkus *et al.*, 1980). Greater root depth and density of rice plants resulted in more available water and nutrients during periods of drought, and these plants maintain a more uniform transpiration rate (O'Toole, 1982).

The amount of vertical force required to uproot a rice plant is known as root pulling resistance (RPR) (O'Toole and Soemartono,1981). RPR is positively correlated with root length density (RLD) which is the development of a root system in the deeper soil profile (Ekanayake *et al.*, 1986). The RPR technique was used at IRRI to screen rice genotypes under transplanted conditions. Data are not available on this technique for direct seeded rice. Experiments were conducted in 1988 and 1989 to evaluate RPR and its applicability as a screening tool to evaluate rice germplasm for drought tolerance under dry seeded conditions.

MATERIALS AND METHODS

Experiments were conducted in 1988 and 1989 at the University of Arkansas at Pine Bluff Agricultural Experiment Station. Fifty genotypes that originated in 4 countries (Pakistan, Philippines, India, and U.S.A.) were grown on Calloway silt loam soil with two water treatments described below. Three seeds per hill were seeded in 2 rows of 10 hills each. Hills were spaced 40 cm apart so that, when a plant was pulled for RPR measurement, the next plant remains undisturbed. The tests were seeded June 3 in 1988 and June 1 in 1989. Between 5 and 7 days after emergence the seedlings were thinned to 1 plant per hill. Experiments were conducted in a randomized complete block (RCB) design with a split-plot arrangement. In each of 4 blocks (replications), genotypes as subplots were randomized within an irrigation treatment as a mainplot. Rice was flooded 2 weeks after emergence. Between 5 and 10 cm of water was maintained in the irrigated plots throughout the season while rainwater was immediately drained from the non-irrigated plots. The tests received 33 and 53 cm of rainfall in 1988 and 1989, respectively. Normal rainfall for this period is about 49 cm (Arkansas Agricultural Statistics Service, 1989).

Nitrogen (Urea) was applied in 3 splits; the first was a preflood application of 56 Kg N/ha, and that application was followed by 29 Kg N/ha at 30 days and another 29 Kg N/ha at 45 days after seeding in 1988. The third split of N was not applied in 1989.

Data were collected on maximum root length (RL), total root number (RN), root dry weight (RWT), and RPR measurements. Data on shoot components consisted of plant height (PHT), days to 50% heading (DH), and grain yield and were measured in 1989 only.

The RPR measurements were taken only from the irrigated plots at 30 and 35 days after emergence in 1988 and 1989, respectively. RPR and pulled root components were measured as described by O'Toole and Soemartono (1981) and Ekanayake *et al.* (1986). The rice plant was held at the base (ground level) by a clamp attached to a spring balance and was pulled vertically. The force required to uproot the plant was measured by a spring loaded scale and recorded in kilograms. The RPR technique was not designed for screening rice germplasm under dry conditions. However, attempts were made to pull under dry condition, but the stems of the rice plant broke before being uprooted when pulled from the non-irrigated plots, and RPR measurements were not possible.

Analyses of variance for all data and correlations among different traits were performed using SAS (SAS User's Guide: Statistics, 1982 edition. SAS Institute Inc., Cary, NC). Drought tolerant genotypes were identified as those with the higher RPR values.

Screening Rice (*Oryza sativa* L.) Genotypes for Drought Tolerance Under Field Conditions

RESULTS AND DISCUSSION

The genotypes in this study varied widely in PHT, DH, and potential yield (PY). Grain yield on a single plant basis and other above ground plant parameters were measured in the 1989 experiment. The ranges of PHT, DH, and PY under irrigated conditions were 66-177 cm, 73-117 days, and 41-597 g/5 plants, respectively. On an average, PHT was decreased by 17 cm and DH was delayed by 6 days due to non-irrigated conditions. There were significant genotype-by-irrigation interactions for PHT and DH. Grain yield under non-irrigated conditions was 34% less than under irrigated conditions. RPR was not correlated with PHT, DH, or PY. The grain yields of late maturing genotypes were adversely affected by reduced panicle exsertion and reduced spikelet fertility due to low temperature (< 15 °C) in late September. Many of the tall genotypes lodged at flowering. For some genotypes, lodging was less under non-irrigated conditions than under irrigated conditions.

The RPR data were consistent across genotypes in both years. There was a significant correlation ($r = 0.32$, $P > 0.05$) between 1988 and 1989 RPR values. Four plants per entry per replication were sampled for RPR in 1988 as compared to only 2 plants being sampled per entry per replication in 1989. The coefficient of variation (C.V.%) for RPR means was 5.2% in 1988 as compared to 12.7% in 1989. The larger C.V. probably was due to the smaller sample size used in 1989. These data demonstrated that a sample size of 4 plants per replication is sufficient for RPR measurements.

Price *et al.* (1989) showed that RPR was correlated with RL, RN, and RWT in 1988. In the 1989 experiment, the correlations were significant only for RL and RWT, and the magnitudes of correlation coefficient were smaller than in 1988 (Table 1). In general, the correlations were greater for RL and RWT than RN. These data indicated that RL and RWT were the most reliable attributes of deep root system and were reflected in RPR. O'Toole and Soemartone (1981) found RL and RWT to be significantly correlated with RPR, whereas Ekanayake *et al.* (1986) found RL to be nonsignificant and RWT to be highly significant. Data from our tests in 1988 and 1989 show that RWT coupled with RL can be used as an indirect indicator of RPR and consequently root-related drought tolerance.

Table 1. Correlation coefficients (r) of root pulling resistance (RPR) with maximum root length (RL), total root number (RN), and root dry weight (RWT), in 1988 and 1989 experiments.

Experiment		r		
		RL	RN	RWT
1988	RPR	0.69**	0.61**	0.82**
1989	RPR	0.33*	0.11	0.46**

*, ** Significant at 0.05 and 0.01 probability levels, respectively. N=50.

RPR has been found to be correlated with visual drought scores based on leaf rolling, leaf desiccation, and dry matter production at the vegetative stage (Puckridge and O'Toole, 1980; O'Toole and Soemartono, 1981; Ekanayake *et al.*, 1985). In this study, visual rating on leaf rolling and leaf desiccation revealed significant difference among genotypes. However, the relationship between RPR and leaf rolling or between RPR and leaf desiccation was not established. The varying degrees of moisture of the field and differential sensitivity of the genotypes in leaf rolling to water stress, irrespective of RPR values, were probably the reasons for lack of this relationship. Moreover, due to frequent rainfall, the stress was not severe enough to manifest the advantage of high RPR in reducing leaf desiccation.

Puckridge and O'Toole (1980) observed that the higher drought tolerance in the high RPR cultivars was due to increased water extraction from the soil profile. RWT is a function of RL, RN, root branching (RB), and root thickness (RTH). RPR was correlated with both RL and RWT but the greatest correlation was between RPR and RWT in both years (Table 1). Furthermore, genotypes with the highest RWT and RPR performed better under drought stress. The RPR and RWT data for six germplasm accessions and three U.S. rice cultivars are presented in Table 2. These data demonstrated that in geneal, germplasm with a high RPR was accompanied by a high RWT in both 1988 and 1989. The Pakistan accessions 'Munji Sufaid Pak 23B' and 'Dhan Sufaid Pak 299' maintained their high RPR and corresponding RWT in both experiments. Other Pakistan accessions 'Coarse Pak 76 S', 'EB Pak 204', and 'Hansraj Pak 13' had intermediate RPR and RWT. The U.S. cultivars 'Newbonnet', 'Mars', and 'Nortai', as a group, had the lowest RPR and RWT values in both years, but in 1989 the RWT values for these U.S. cultivars were not significantly lower thanthose for some of the Pakistan cultivars.

Table 2. Mean comparison among nine rice genotypes for root pulling resistance (RPR) and root dry weight (RWT) in 1988 and 1989 experiments.

Genotype	Country of Origin	1988 RPR (Kg)	1988 RWT (g)	1989 RPR (Kg)	1989 RWT (g)
Munji Sufaid Pak 238	Pakistan	22.3 a*	2.16 a	16.0 ab	0.57 a
Dhan Sufaid Pak 299	Pakistan	22.2 ab	2.09 b	15.8 ab	0.79 a
Basmati Nahan Pak 381	Pakistan	21.7 b	1.11 e	22.0 a	0.65 a
Coarse Pak 76S	Pakistan	21.6 b	2.11 b	13.2 bc	0.47 bc
EB Pak 204	Pakistan	18.5 c	1.53 c	13.7 bc	0.42 bc
Hansraj Pak 13	Pakistan	15.9 d	1.30 d	13.6 bc	0.52 b
Newbonnet	U.S.A.	14.0 e	0.74 f	10.5 e	0.27 c
Mars	U.S.A.	9.9 f	0.51 h	11.0 de	0.27 c
Nortai	U.S.A.	9.3 f	0.56 g	12.0 cd	0.42 bc
C.V.%		5.2	4.3	12.7	36.2

* Means within columns with the same letters are not significantly different at the 0.05 probability level.

These data suggest that RWT is a direct indicator of RPR. Furthermore, the RPR method as a tool for screening rice germplasm for drought tolerance was shown to have potential in direct seeded rice culture. The development of root systems in terms of RL and RWT was reflected in RPR.

This technique was developed at IRRI to measure root pulling resistance in lowland transplanted culture. The advantage of this technique is that the drought tolerance of rice can be measured without subjecting the rice plant to drought conditions. The RPR technique of screening rice germplasm for root-related drought tolerance is useful in direct seeded U.S. rice culture.

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CONFORMATIONAL AND CIRCULAR DICHROISM STUDIES ON N-ACETYL-L-PROLYL-D-ALANYL-METHYLAMIDE

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ABSTRACT

The compact ordered conformations of the molecule N-Acteyl-L-Prolyl-D-Alanyl-Methylamide have been studied by semiempirical energy calculations in vacuum and circular dichroism (CD) in solution.

The presence of ordered structure has been observed in hydrogen bond promoting solvents like trifluoroethanol by CD studies. In hydrogen bond breaking solvents, like trifluoroacetic acid (TFA), significant fraction of the ordered conformers probably assume extended conformation without intramolecular hydrogen bonds and perhaps are in equilibrium with the fraction of compact ordered structures. The trend observed in going from nonpolar to polar solvent is also compatible with the previous NMR studies in solution.

The semiempirical energy calculations have been carried out in the allowed region for β-bends. The flexibility of pyrrolidine ring has been incorporated into the calculations. Representative puckerings, namely, A-type (Cγ-*exo*) and B-type (Cγ-*endo*) have been considered in this study. The results show the B-type to be slightly preferred over the A-type in this tripeptide moiety. The minimum energy conformation predicted from these studies agree only minimally with that found in crystal structure. A better agreement is found after performing the calculations using the geometrical data as observed in the crystal structure of this molecule. Our studies demonstrate that solvent solute interactions are minimal in nonpolar solvents and the predicted minimum energy conformations are preserved at least in nonpolar solvents.

INTRODUCTION

A detailed understanding of the conformation of peptide structures with both L and D amino acid residues are of importance in connection with the studies on cyclic peptides and antibiotics which may consist of either kind of amino acid residues. The key points of reversal in the chain direction in such peptides consisting of both L and D amino acid residues may be expected to be LD or LG sequences (where G denotes a glycyl residue) rather than LL sequences (Chandrasekaran *et al.*, 1973). The LL and LG sequences, however, are found to be important in the folding of polypeptides and proteins. In globular proteins, a chain reversal often enables different parts of the molecule to come close and form a compact structure. Such a chain reversal facilitates ring closures in many cyclic peptides and antibiotics. Chain reversals have been observed in many proteins (Birktoft and Blow, 1972; Blake *et al.*,., 1967; Lipscomb *et al.*,., 1976; Kartha *et al.*,., 1967) and cyclic and linear peptides (Ueki *et al.*,., 1969; Rudko *et al.*,., 1971; Karle *et al.*,., 1970; Zalkin *et al.*,., 1966; Reed and Johnson, 1973; Brahmachari *et al.*,., 1981; Ayato *et al.*,., 1981; Yagi *et al.*,., 1983; Pichon-Pesme *et al.*,., 1988; and Ananthanarayanan and Cameron, 1988).

The optimum size required for a compact reversal to occur is just a tripeptide. The earlier studies on three-linked peptide units from purely stereochemical considerations (Venkatchalam, 1970) and later detailed studies from energy considerations have shown that stable folded conformations with a 4—>1 type (IUPAC-IUB Commission on Biochemical Nomenclature, 1970) internal N-H...0 bond are possible. Such conformations are well known as β-bends or β-turns.

The various interesting features of the theoretical predictions were: (i) low energy β-bends can occur near the α-helical conformation and hence a chain reversal can occur in the vicinity of an α-helix (ii) the conformational angle ϕ_2 at $C_2\alpha$ being very close to that for a proline residue, a sequence of the type -pro-x- can be a ready site for a β-bend. Also, it was evident from these studies that while a pyrrolidine ring can be easily accommodated at $C_2\alpha$ in LL bends, it can occur equally well at either $C_2\alpha$ or $C_3\alpha$ in LD bends.

As discussed earlier, β-turns or reverse turns are important structural features in proteins and bioactive peptides and may play an important role in protein folding. There has been a continued interest in such compact secondary structures and has been an active area of research through studies on a variety of model compounds by both theoretical and experimental methods. Several model compounds and macromolecules consisting of such bends have been studied by infrared spectroscopy (IR), (Bandekar and Krimm, 1979; Krimm and Bandekar, 1980; Naik and Krimm, 1984) nuclear magnetic resonance (NMR), (Brahmachari *et al.*, 1981; Narasinga Rao *et al.*, 1983; Ramaprasad *et al.*, 1981; Patel and Tonelli, 1973; Pitner and Urry, 1972; Khaled *et al.*, 1976; Pelton *et al.*, 1988; and Jelicks *et al.*, 1988) and circular dichroisum (CD) Kawai and Fasman, 1978; Brahmachri *et al.*, 1979, and Crisma *et al.*, 1984). In addition, several theoretical calculations have been attempted by a variety of minimization techniques to predict the possible conformations. In their studies, Pletnev *et al.* (1974) have considered a short peptide (Ac-Gly-L-Ala-Gly-NHMe) with intramolecular hydrogen bonds for a detailed theoretical analysis. Zimmerman *et al.* (1982) have studied in detail the tripeptide H-L-Pro-L-Leu-Gly-NH_2. They calculated lowest energy for type II β-bend and was similar to that reported in an X-ray crystal study.

To have an insight into the details of the folded conformation with different side chains at $C_2\alpha$ and $C_3\alpha$ in either L or D configuration a series of spectroscopic and theoretical studies have been undertaken by the author and the results on the molecule N-acetyl-L-prolyl-D-alanyl-methylamide from CD studies and semiempirical energy calculations are presented in this paper. While the circular dichroism studies are compatible with the previous NMR studies on this molecule, semiempirical energy calculations show only marginal agreement with the conformation observed in the solid state.

CD STUDIES

EXPERIMENTAL PROCEDURES

Materials — The tripeptide was given as a gift by Dr. K.S.N. Iyer. It was dried overnight under vacuum in the presence of P_2O_5 before making the measurements. The purity of solvents were checked by the uv absorption spectra.

Spectral measurements — Spectra were recorded using the JASCO J-20 spectrometer. The parameters like chart speed, time constant, wavelength expansion and gain contraols were so chosen as to obtain the best signal-to-noise ratio and reproducibility of the spectra. Mean residue ellipticity values are expressed as deg-cm²/decimole and have not been corrected for the effect of refractive index of the solvent. All the measurements were done at ambient temperature (25 °C).

The solution for CD measurements was prepared by dissolving the required amount of the tripeptide in a known volume of the solvent. Cells with a path length of 0.1 to 0.2 cm were employed. The peptide concentrations (expressed as gm per 100 ml of solvent) were around 0.1 to 0.2%. In a given run, the concentration was maintained constant during the searching of the entire accessible wavelength region (210-240 nm). Since there were no signs of aggregation as obtained by our previous NMR studies at even higher concentrations, no concentration dependent CD studies were carried out.

RESULTS AND DISCUSSIONS ON CD STUDIES

The CD spectra of this peptide in both the solvents are recorded in Fig. 1. Only 1 CD extrema, namely $[\theta]_{222} = -7733$, is clear while the peak around $[\theta]_{205}$ can not be obtained from this study. It is interesting to note that the trough at 225 nm is typical of type I and type II β-bend. Further characterization of a particular bend type will require studies similar to those by Brahmachari *et al.* These preliminary studies, however, very well characterize the peptide moiety as an ordered structure.

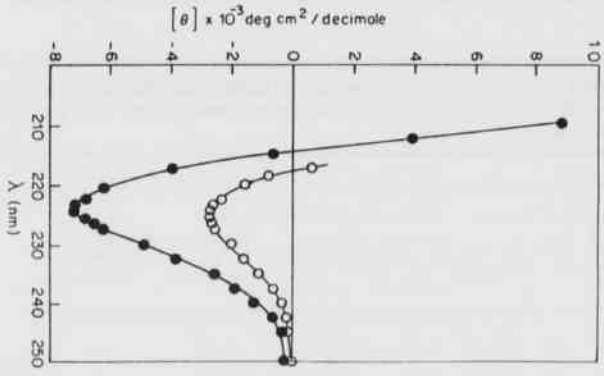

Figure 1. Circular dichroism spectra of the tripeptide in TFE (-•-•-) and TFA (-O-O-).

These studies clearly demonstrate that the $[\theta]_{222}$ decreases in magnitude as the solvent changes from TFE (nonpolar) to TFA the hydrogen bond breaking solvent by about 3-fold. This possibly means that the fraction of ordered β-turns conformers have decreased significantly in going from TFE to TFA.

The results from CD studies may be usefully compared with those of previous NMR studies (Ramaprasad, 1981) in nonpolar solvents like $CDCl_3$. Both ^1H and ^{13}C NMR have shown that the major conformers in $CDCl_3$ are compact folded β-bends while in more polar solvents, because of *cis-trans* isomerization about the x-pro bond, the fraction of β-bend conformers decreases. The significant decrease in the fraction of ordered structures upon solvent change from TFE to TFA is probably because of random structures generated from the breaking of intra molecular 4—>1 hydrogen bonds and/or cis-trans isomerization about the x-pro bond as observed from NMR.

THEORETICAL

PROCEDURAL DETAILS

A schematic diagram of the molecule is shown in Fig. 2. The IUPAC-IUB conventions (IUPAC-IUB Commission on Biochemical Nomenclature, 1970) have been used to denote the conformational angles.

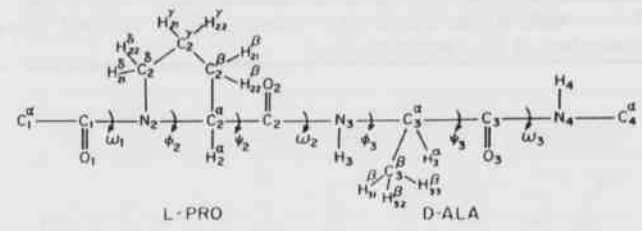

Figure 2. The structural formula of the molecule N-acetyl-L-prolyl-D-alanyl-methylamide. The various backbone dihedral angles are also shown.

In this study *trans* planar peptides have been used. The hydrogen atoms in the pyrrolidine rings have been fixed by bisecting the appropriate C-C-C or C-C-N angles. The bond angles N_2-$C_2\alpha$-C_2 and N_3-$C_3\alpha$-C_3 in the main chain have been maintained at the expected value of 100°. All the H-C-H bond angles have been taken to the 109.5° and the C-H bond lengths to be 1.1 A°. The hydrogens of the terminal methyl groups at $C_1\alpha$ and $C_4\alpha$ have not be considered separately, but are treated as single 'effective' atoms with increased Van der Waals radii. The methyl hydrogens of the alanine residue have been fixed in the staggered position.

GEOMETRY OF THE PYRROLIDINE RING

The pyrrolidine ring is puckered and this has been taken into account while incorporating the same into the tripeptide system. Ramachandran and colleagues (1968) have classified the puckering into two main categories, namely, type A(C^γ-*exo*) and type B (C^γ-*endo*), and these are illustrated in Fig. 3. They essentially differ in the sign of the dihedral angles about the various bonds of the ring.

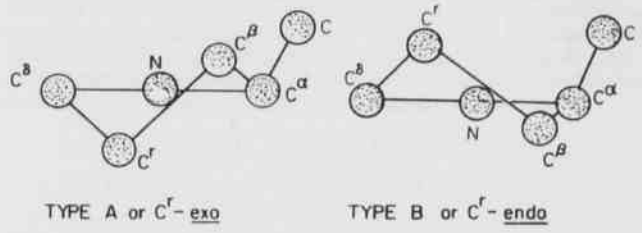

Figure 3. Schematic representation of the two major types of puckering of the pyrrolidine ring.

In the present study, five different representative puckerings have been selected from the list of low energy conformers of the pyrrolidine ring (see Table 2 in Ramachandran, 1970). The selected puckers are designated A_1, A_2, A_3, B_2 and B_3 and they correspond to values in the range −50° to 70°. The endocyclic bond angles and the ring dihedral angles for each puckering is given in Table 1.

THE GENERATION OF THE TRIPEPTIDE

To accommodate the pyrrolidine ring in the main chaing, the angle ϕ , at $C_2\alpha$ was assigned an appropriate value using the relation $\phi = \theta - 60°$. To generate different tripeptide conformations, the remaining three main chain dihedral angles viz., ψ_2, ϕ_3 and ψ_3 were varied, in the allowed region for an LD bend[1], at intervals of 10°. The criteria now used for selecting 4—>1 hydrogen bonded structures were that the $N_4 \ldots O_1$ distance be between 2.6 and 3.2 Å and the $NH_AN \ldots O$ be less than 35°. For each of these conformers the total conformational energy was evaluated.

Conformational and Circular Dichroism Studies on N-Acetyl-L-Prolyl-D-Alanyl-Methylamide

Table 1. Bond Angles and the Ring Torsion Angles for the Five Chosen Puckerings of the Pyrrolidine Ring*

Puckering	Bond Angles (in degrees) $N\text{-}C^{\alpha}\text{-}C^{\beta}$	$C^{\alpha}\text{-}C^{\beta}\text{-}C^{\gamma}$	$C^{\beta}\text{-}C^{\gamma}\text{-}C^{\delta}$	$C^{\gamma}\text{-}C^{\delta}\text{-}N$	$C^{\delta}\text{-}N\text{-}C^{\alpha}$	Ring Dihedral Angles (in degrees) θ	χ^1	χ^2	χ^3	χ^4	Energy kcal/mole
C^{γ}-exo											
A_1	103	106	106	103	113	10	-25	31	-24	8	12.50
A_2	103	106	105	102	113	0	-20	33	-31	20	12.19
A_3	103	106	106	100	113	-10	-13	31	-35	28	12.98
C^{γ}-endo											
B_2	103	106	105	102	113	0	20	-33	31	-20	12.16
B_3	103	106	106	103	113	-10	25	-31	24	-8	11.80

* From Ramachandran et al (1970).

EVALUATION OF CONFORMATIONAL ENERGY

The total conformational energy of the molecule was computed using the empirical potential functions (Ramachandran and Sasisekharan, 1968). The total energy is the sum of the contributions from nonbonded and electrostatic interactions and those due to torsional potential as well as the bond angle distortions. The non-bonded energy was evaluated using 6-exp potential functions with the constants given by Chandrasekaran and Balasubramanian (1969). The charges (see Table 2) were computed following the semiempirical methods of Del Re (1963) and Pullman (1963, 1965). The hydrogen bond energy was evaluated according to the method of Ramachandran *et al.* (1971).

Table 2. Patial Charges* (in e.s.u.) for the Molecule of N-Ace-L-Pro-D-Ala-MeA.

Atom	Charges	Atom	Charges
C_1^{α}	-0.095	N_3	-0.200
C_1	0.339	H_3	0.207
O_1	-0.472	C_3^{α}	0.050
N_2	-0.049	C_3^{β}	-0.110
C_2^{α}	0.040	C_3	0.339
C^{β}	-0.070	O_3	-0.450
C^{γ}	-0.070	N_4	-0.185
C^{δ}	-0.030	H_4	0.196
C_2	0.339	C_4^{α}	-0.075
O_2	-0.450		

* The charge on hydrogen atoms attached to SP^3-type carbons, on an average, is 0.04 (in e.s.u.).

RESULTS AND DISCUSSION

Examples of the minimum energy conformers for each of the chosen puckerings is given in Table 3. These values range from -1.9 kcal/mole to -3.2 kcal/mole. Among the 5 minimum energy conformers listed in Table 3, the B_3 conformer has the lowest energy of -3.2 kcal/mole. From the same list of values it may be noticed that B_2 and B_3 conformers are energetically more favorable than the corresponding A_2 and A_3 conformers (C^{γ}-*exo* type puckers) by 0.4 and 0.7 kcal/mole respectively.

For the type A conformers, the minimum energy for the tripeptide is -2.5 kcal/mole. Similarly, the minimum energy for B-type is -3.2 kcal/mole. Thus, between type A and type B the latter is energetically more favorable than the former by about 0.7 kcal/mole. Although, the minimum energy conformation may be expected to occur in the solid state, that is not the only stable conformation which can occur. As such, many low energy conformers extending in energy up to 0.6 kcal/mole from the minimum are recorded in Table 4. It is interesting to compare the minimum energy conformation with that obtained from the crystal structure analysis (Ramaprasad, 1980). On comparing the conformational angles predicted from theory and those obtained from cyrstal structure analysis, there is only an approximate agreement between the two (the one corresponding to crystal structure and one to energy calculations using standard bond lengths and angles). The relative displacement of the two models with respect to the dihedral angles ψ_2 and ψ_3 have been shown diagramatically in Figs. 4 and 5. While drawing these plots, the values of ϕ_2 and ϕ_3 have been kept fixed at values

Table 3. Minimum Energy Conformations of the Tripeptide Molecule for the Five Chosen Puckerings of the Pyrrolidine Ring.

Puckering of Proline	ϕ_2(°)	ψ_2(°)	ϕ_3(°)	ψ_3(°)	Total Energy kcal/mole
C^{γ}-exo					
A_1	-50	130	110	-40	-1.9
A_2	-60	100	60	40	-2.4
A_3	-70	100	80	30	-2.5
C^{γ}-endo					
B_2	-60	100	60	40	-2.8
B_3	-70	100	80	30	-3.2

Table 4. Characteristics of Low Energy Conformations with the Corresponding Hydrogen Bond Parameters and Their Energies of Stabilization.

Dihedral Angles ϕ_2 (°)	ψ_2 (°)	ϕ_3 (°)	ψ_3 (°)	Hydrogen Bond Parameters: Length $N_4 \cdots O_1$ (Å)	Angle $N_4H_4\overset{\frown}{A}N_4O_1$ (°)	Energy V_{hb} (kcal/mole)	Total Stabilisation Energy (kcal/mole)
-70	100	80	30	3.07	16.5	-3.95	-3.2
-70	90	90	30	3.03	15.0	-4.14	-3.2
-70	100	90	30	3.80	23.9	-3.92	-3.1
-70	100	90	20	2.94	13.4	-4.32	-2.9
-70	100	80	20	3.03	7.4	-4.28	-2.9
-70	90	90	20	3.00	4.3	-4.42	-2.9
-70	90	100	30	2.96	22.1	-4.02	-2.9
-70	90	90	40	3.11	27.0	-3.36	-2.8
-70	100	130	-30	2.99	26.8	-3.80	-2.7
-70	100	80	40	3.14	28.0	-3.03	-2.6
-70	110	80	30	3.06	25.5	-3.68	-2.6
-70	90	100	20	2.90	10.8	-4.32	-2.6
-70	110	80	20	3.00	15.9	-4.21	-2.6

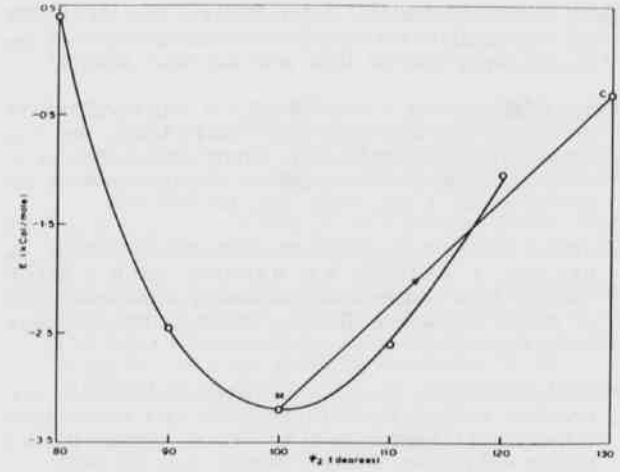

Fig. 4

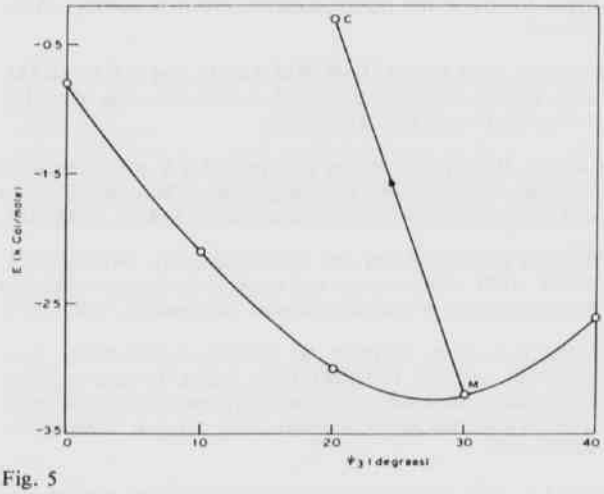

Fig. 5

Figure 4-5. Plots of conformational energy E (computed using the standard bond lengths and bond angles) Vs. ψ_2 and ψ_3 respectively. C and M denote the crystallographically observed and the predicted minimum energy conformations respectively.

corresponding to the minimum energy conformation. The differences in the dihedral angles between the X-ray structure and the minimum energy model can be seen in these diagrams wherein both of them have been indicated. This is more clear on comparing the set of conformational angles, namely (ϕ_2, ψ_2) and (ϕ_3, ψ_3) at $C_2\alpha$ and $C_3\alpha$ respectively, obtained from theory and experiment. The values predicted from the theory are (−70°, 100°); (80°, 30°) while those obtained from crystal structure analysis are (−66°, 127°); (75°, 12°).

As a final step in refinement in the calculations the influence of the change in geometry of the molecule on the results was considered. The calculations were performed using the observed pyrrolidine puckering and the data on bond lengths and angles as found in the crystal structure. In these calculations the rotational angles ψ_2, ϕ_3 and ψ_3 alone were varied at intervals of 10° in the allowed region for LD-bends. The low energy values are listed in Table 5. The observed conformation is shifted from the predicted minimum by about 1.0 kcal/mole. The plots of conformational energy (calculated using the crystal structure data) vs. ψ_2 and ψ_3 are shown in Fig. 6 and 7 respectively. The observed conformation is also indicated in this diagram. It is clear that an energy difference

Table 5. Characteristic Low Energy Conformers in Regions around the Observed Crystal Structure.

Dihedral Angles				Hydrogen Bond Parameters			Total Stabilisation Energy
ϕ_2 (°)	ψ_2 (°)	ϕ_3 (°)	ψ_3 (°)	Length $N_4\cdots O_1$ (Å)	Angle $N_4H_4\cdots N_4O_1$ (°)	Energy V_{hb} (kcal/mole)	(kcal/mole)
-66	107	75	22	2.92	7.2	-4.4	-3.3
-66	107	65	22	3.00	2.6	-4.4	-3.3
-66	97	75	22	3.00	2.1	-4.5	-3.3
-66	107	65	32	3.00	10.8	-4.2	-3.2
-66	97	75	32	3.00	11.5	-4.2	-3.1
-66	107	75	12	2.90	8.4	-4.3	-3.1
-66	107	75	32	3.00	18.9	-4.1	-3.1
-66	97	85	22	2.90	6.1	-4.4	-3.1
-66	117	65	22	2.95	9.1	-4.4	-3.0
-66	97	75	12	3.00	13.8	-4.3	-2.9
-66	97	85	32	3.00	18.6	-4.2	-2.9
-66	997	85	12	2.90	6.7	-4.3	-2.9
-66	107	85	22	2.90	15.2	-4.1	-2.9
-66	107	85	12	2.80	6.1	-4.1	-2.8
-66	117	65	32	3.00	19.2	-4.1	-2.8
-66	117	75	22	2.90	16.5	-4.2	-2.8
-66	117	75	12	2.90	9.6	-4.2	-2.7
-66	107	65	12	3.00	14.8	-4.2	-2.7
-66	127	75	12	2.90	16.2	-4.2	-2.3*

* This energy value corresponds to the conformation observed in the crystal structure.

of about 3 kcal/mole between the minimum energy conformation and the observed one is reduced by 2 kcal/mole on using the geometrical values (excepting ψ_2, ϕ_3 and ψ_3) and the pyrrolidine puckering as observed in the crystal structure. A difference in energy of 1.0 kcal/mole has probably been compensated by intermolecular interactions.

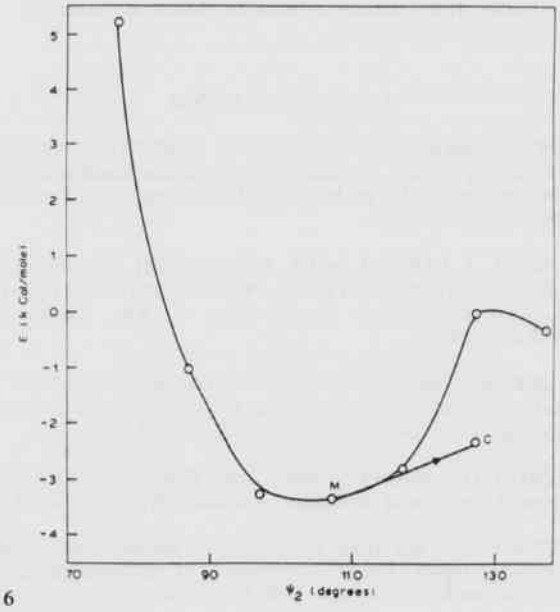

Fig. 6

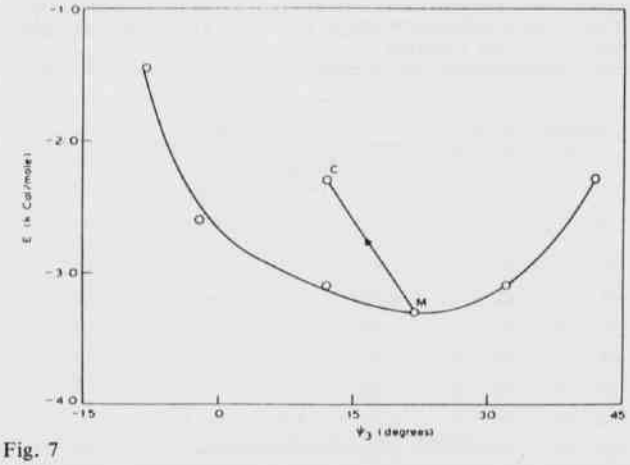

Fig. 7

Figure 6-7. Plots of conformational energy, E (computed using the observed bond lengths and bond angles) Vs. ψ_2 and ψ_3 respectively. C and M refer to the crystallographicaly observed and the predicted minimum energy conformations respectively.

CONCLUSIONS

The CD studies demonstrate that the tripeptide is more ordered in TFE than in TFA. In TFA the fraction of ordered structure has been reduced as compared to that in TFE.

The energy calculations with flexible pyrrolidine ring show that the B-type is slightly preferred over the A-type. The results compare only minimally with those from X-ray structure analysis. The theoretical results, however, compare better when geometrical data as observed in the crystal structure are used. These studies point out the need for bond length and angle deviations in similar energy calculations.

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SEXUAL DIMORPHISM AND INTERSEXUAL DIFFERENCES IN RESOURCE ALLOCATIONS OF A DIOECIOUS SHRUB, *LINDERA MELISSIFOLIA* (WALT.) BLUME.

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ABSTRACT

Morphometric data were gathered to make intersexual comparisons on the morphology and reproductive resource allocation patterns of the rare, dioecious shrub, *Lindera melissifolia*. Females produced significantly fewer flowers and leaves than did males. No other significant differences could be detected in morphology. Female "clones" exhibit low area coverage and low stem density, which suggests higher costs of reproduction. If this is the case, the deficits produced in resource allocations directed toward sexual reproduction seem to result in increased mortality and/or reduced vegetative reproduction.

INTRODUCTION

In some dioecious plant species there may be marked differences between males and females due to their differential costs of reproduction (Lloyd and Webb, 1977; Meagher and Antonovics, 1982). Females tend to suffer more in normal vegetative growth when they sexually reproduce because it is more metabolically expensive (Putwain and Harper, 1972; Lloyd and Webb, 1977; Hoffmann, 1981; Meagher and Antonovics, 1982; Agren, 1988; Lovett Doust and Lovett Doust, 1988). One remarkable adjustment to the fact that females do have a greater cost in sexual reproduction was found in the case of *Simmondsia chinensis*. The females of this species have developed mechanisms for optimizing water, carbon, and nutrient use. They have allowed less resources to stem biomass but have developed larger leaves in order to maintain photosynthetic levels. They have developed a more open canopy than males with less vegetative biomass and have thickened their leaves for maximum water storage (Wallace and Rundel, 1979). This has allowed the sexes to remain relatively equal.

Another interesting adjustment exhibited by some species in response to reproductive resource allocations is the ability of individuals to switch in either direction between a male phase and female phase. Schlessman (1987) observed gender modification in *Panax trifolium* to be connected to the amount of stored resources available for the maturation of fruit. Policansky (1987) found that *Arisaema triphyllum* could "choose" their sex based on the size of the individual, with the larger individuals becoming females due to their greater reproductive potential.

The purpose of this study was to make intersexual comparisons on the morphology of the dioecious shrub, *Lindera melissifolia*, and to examine reproductive resource allocations within the species.

THE SPECIES

Lindera melissifolia (Walt.) Blume. is a low shrub, 0.6-2 m tall. Plants are stoloniferous and generally grow in putative "clones" of numerous stems that individually are not highly branched. Flowers are dioecious and small; the flowers of both sexes are pale yellow in color, but female flowers are less conspicuous than male (Steyermark, 1949). Fruits are approximately 1.25 cm long at maturity and are of brilliant scarlet color. The flowers appear in March in Arkansas, while mature fruits are present in October (Tucker, 1983; Steyermark, 1949).

Pondberry, listed as endangered by the U.S. Fish and Wildlife Service, occurs across the southeastern section of the country with reported occurrences in North Carolina, Georgia, Mississippi, Missouri, Tennessee, and Arkansas. It has apparently been extirpated from Alabama, Florida, and Louisiana (Tucker, 1983). Locally, pondberry occurs in topographically isolated depressions in dunefields extended across eastern Arkansas and into southeastern Missouri (Wright, 1989b). Generally, these depressions are inundated in winter and early spring, with the water receding during the early portion of the growing season (Tucker, 1983). Wright (1989a) observed that the frequency and size of single-sex "clones" suggests that sexual reproduction may be ineffective.

STUDY SITE

The study site consists of a large undisturbed population of pondberry growing in a dunefield depression northeast of Swifton, Jackson County, Arkansas. The depression encompasses approximately 10,000 m^2 and contains 11 single-sex stands (hereafter termed "clones") of pondberry; 6 male and 5 female (Fig. 1). The male "clones" collectively cover an aera of 3,262 m^2 with individual "clones" ranging in area from 21 m^2 to 1211 m^2. The female "clones" collectively cover an area of 155 m^2 with individual "clones" ranging in area from 1 m^2 to 95 m^2.

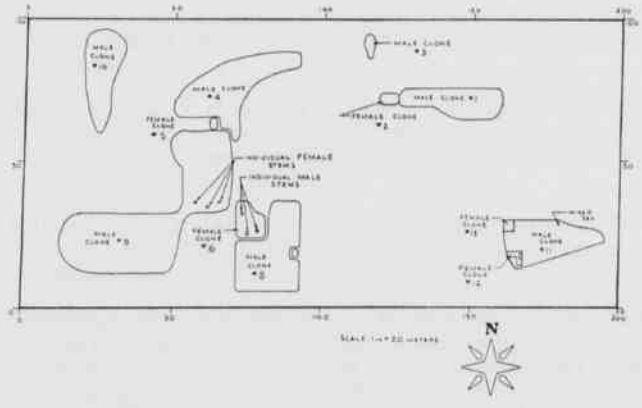

Figure 1. Map of study site.

MATERIALS AND METHODS

FIELD MORPHOLOGICAL MEASUREMENTS AND OBSERVATIONS

On March 18, 1989, morphological measurements were taken from 397 individual stems. Six 1 x 1 m quadrats were randomly constructed within each "clone". Nine of the 11 "clones" were sampled; "clones" 10 and 11 were censused due to their small size. Measurements were taken from 4 flowering and 4 vegetative stems from each quadrat. Vegetative stems in "clones" where all flowering stems were of one sex were presumed to be one of the same sex, a procedure followed by Agren (1988) in a study of Rubus chamaemorus. The process of stem selection was randomized by selecting the flowering and vegetative stems nearest each corner of the quadrat. In the same quadrats, all stems were counted to determine stem density.

The height of each stem was measured from the ground to the tip of the tallest terminal branch. The living height of each stem was measured from the ground to the beginning of winter dieback (stems can experience some dieback but resume growth in spring) (Steyermark, 1963). The number of terminal branches was determined for each stem, as well as the number of flowers.

On May 6, 1989, morphological measurements were taken from the leaves of 162 individual stems; 81 male and 81 female. Stems were randomly selected from male "clones" 4, 8, and 9 and female "clones" 13, 5, and 6 at fixed intervals along a randomly constructed transect through each "clone". The number of leaves from the lowest terminal branch of the lowest main branch of each stem was counted. The length from the base of the blade to the apex, width at the widest point, and petiole length of the third fully expanded leaf of the lowest terminal branch of the lowest main branch on each stem were measured.

On May 23, 1989 fifty female stems, from within the population, were marked in order to determine if *Lindera melissifolia* possesses the capability to change sexual state from female to male.

DESTRUCTIVE HARVESTS

On March 18, 1989 a random sample was made of 40 stems, 23 male and 17 female, from widely distributed areas of the population. The stems were detached at ground level and brought back to the laboratory intact. Stems were dried for 24 hours at 75° C, then weighed to obtain total biomass. The number of annual growth rings was counted and base diameter measured for each stem.

RESULTS

SEX CHANGE DATA

On march 16, 1990 the 50 marked female stems were examined and all flowering stems were determined to be female.

STEM DENSITY, TOTAL HEIGHT, LIVING HEIGHT, NUMBER OF BRANCHES, AND FLOWER NUMBER

In order to examine intersexual differences only, the data from all male "clones" were pooled, as were the data from female "clones". Mean stem density of all male "clones" was 14.11 ± 0.87 SE/m². For all female "clones" mean stem density was 8.80 ± 1.45 SE/m² ($P < .01$, t-test).

Multivariate tests of significance conducted between flowering and vegetative stems among total height, living height, and number of branches using the SPSS-X MANOVA procedure (SPSS, 1983) reflected a significant difference in the 2 groups ($P < .001$). Univariate F-tests reflected significant differences ($P < .001$) for each character measured between flowering and vegetative stems.

In order to determine if there were any intersexual differences in vegetative and flowering stems, multivariate tests of significance for sex by status (flowering and vegetative) among total height, living height, and number of branches were conducted using the SPSS-X MANOVA procedure. No significant differences were detected. Since there were no significant differences between sexes among flowering and vegetative stems, the 2 groups were pooled and the population was examined only for intersexual differences.

Multivariate tests of significance conducted between sexes among total height, living height, number of branches, and flower number, using the SPSS-X MANOVA procedure, reflected a significant difference in the 2 groups ($P < .01$). Univariate F-tests reflected a significant intersexual difference ($P < .01$) in the number of flowers per stem. Female stems had significantly fewer flowers than did male stems (mean ± SE: female 29.5 ± 4.3, $n = 57$; male 623.0 ± 7.9, $n = 96$; $P < .01$). No significant differences were found in total height, living height, or number of branches.

LEAF LENGTH, LEAF WIDTH, PETIOLE LENGTH, AND LEAF NUMBER

Multivariate tests of significance conducted between sexes among leaf length, leaf width, petiole length, and leaf number, using the SPSS-X MANOVA procedure, reflected a significant difference in the 2 groups ($P < .05$). Univariate F-tests reflected a significant intersexual difference ($P < .01$) in the number of leaves per branch. Female branches had significantly fewer leaves than did male branches (mean ± SE: female 6.1 ± 0.1, $n = 81$; male 6.6 ± 0.1, $n = 81$; $P < .01$). No significant differences were found in leaf length, leaf width, or petiole length.

TOTAL BIOMASS, STEM DIAMETER, AND RING NUMBER

Descriptive statistics and t-tests were conducted for total biomass, stem diameter, and ring number using the StatPac Gold Statistical Analysis Package (1987).

The mean total biomass of stems harvested was (mean ± SE): female 9.04 ± 1.06 g, $n = 17$; male 12.40 ± 1.7 g, $n = 23$. The mean stem diameter of stems harvested was: female 5.1 ± 0.3 cm, $n = 17$; male 5.7 ± 0.3 cm, $n = 23$). The mean ring number of stems harvested was: female 2.8 ± 0.2, $n = 17$; male 3.3 ± 0.3, $n = 23$. The descriptive statistics suggest that male stems have greater total biomass, greater ring number and larger stem diameter; however, multivariate tests of significance conducted between sexes among these characters, using the SPSS-X MANOVA procedure, found no significant differences. A one tailed t-test between sexes demonstrated male stems to have a significantly greater number of annual growth rings than female stems (t 1.93, $P < .05$).

DISCUSSION

Female stems that were marked and re-examined in the subsequent season showed no evidence of sex change.

The only significant intersexual differences, among the morphometric characters measured, that might constitute sexual dimorphism in *Lindera melissifolia* were flower number and leaf number. Male stems in the population have over twice the number of flowers as females; in addition, females develop fewer leaves per branch than do males. What, if any, is the significance of these findings in relation to the phenology of reproductive resource allocations within the species?

Obviously, males will not incur any reproductive expenditure beyond flowering (Gross and Soule, 1981). Females, on the other hand, must endure the added reproductive costs of fruit production, making the total female reproductive effort potentially greater than that of males. This being the case, a male-biased floral sex ratio would be beneficial to the female, which has allocated a substantially greater amount of resources to each individual flower. Darwin (1877) and several later authors have suggested that in many species, females spend more resources on fruiting and flowering than males do on flowering (Barrett and Helenrum, 1981). Lloyd and Webb (1977) pointed out that selection could cause females to spend proportionately less of their resources on sexual reproduction by producing fewer flowers than males. In other words, differences between the sexes could adapt males and females to their distinct reproductive roles.

Leaf number and size may reflect differences in resource allocations. Females of dioecious species could conceivably accommodate higher reproductive expenditures by allocating resources, possibly used by males to produce a greater number of flowers, to the production of leaves and other photosynthetic structures during the growing season (Gross and Soule, 1981; Lloyd and Webb, 1977). This is not the case with *Lindera melissifolia* in which females produced significantly fewer leaves per branch than did males, with no significant differences in leaf size or branch number. This would tend to place females at a disadvantage having less photosynthetic surface with which to meet higher reproductive expenditures. A similar situation is found in *Rubus chamaemorus* in which fruit-producing female ramets formed leaves that were 10-25% smaller than the leaves produced by male ramets and by female ramets whose flowers had been excised to prevent fruit development (Agren, 1988).

Although not statistically significant, there appears to be a trend for male stems to have a greater total biomass, more annual growth rings, and a larger diameter. This trend of "male vigor" need not absolutely be attributed to intersexual reproductive resource allocations, since biomass is not necessarily distributed in equivalent ways in plants, and may often vary between the sexes among dioecious species (Agren, 1988; Abrahamson and Caswell, 1982; Wallace and Rundel, 1979).

Although morphological differences, aside from flower and leaf number, cannot be detected from the characters examined in this study, the female may still bear a heavier reproductive burden than the male. It appears that sexual reproduction in *Lindera melissifolia* is ineffective, evidenced by the presence of large single-sex "clones" (Wright, 1989a). The study population has a highly male-biased sex ratio, with male "clones" covering 95.55% of the total area and having a mean stem density 1.6 times that of the female "clones". This appears to be an extreme case in comparison with other dioecious species. Other male:female ratios reported in the literature include *Ilex montant*, 1.35:1 (Cavigelli *et al.*, 1986) and *Compsoneura sprucei*, 1.25:1 (Bullock, 1982). Bullock (1982) suggested that biased sex ratios may sometimes be the result of increased growth and vigor in males, and not increased mortality of females. Cavigelli *et al.* (1986) indicated that spatial segregation is a secondary implication of sexual dimorphism. Bawa and Opler (1977) pointed out that spatial segregation could be caused by vegetative multiplication, and that segregation of the sexes could diminish sexual reproduction because the probability of finding a mate is fixed by location. Taking these findings into consideration, it seems likely that, if indeed reproductive costs are greater for the females, the deficits are felt predominantly at the level of the "clone" rather than at the individual stem. The only case of deficits resulting from increased reproductive expenditures possibly being reflected at the level of the stem is that of leaf number. Since the time of leaf production coincides with the enlargement of fruit, females may produce fewer leaves as a result of competition for resources between the developing leaves and fruit. Greater reproductive expenditures by females may result in higher stem mortality and/or reduced vegetative stem production (Lovett Doust and Lovett Doust, 1988; Hancock and Bringhurst, 1980; Grant and Mitton, 1979). Elevated costs of reproduction are commonly expressed at the "clonal" level through male-bised sex ratios (Lovett Doust and Lovett Doust, 1988; Lloyd and Webb, 1977; Sohn and Policansky, 1977). Males can sometimes tolerate high densities better than females (Lovett Doust *et al.*, 1987).

If females allocate a greater proportion of their available energy to reproduction than do males, it stands to reason that females would have a smaller proportion of energy available for growth and maintenance (Gross and Soule, 1981; Harper and Ogden, 1970). This energy deficit would be compounded in *Lindera melissifolia* by decreased leaf production in females resulting in fewer photosynthetic structures which, if present, might help bear the cost of fruit production. If these energy deficits are not felt at the level of the stem, it follows that there could be reduced vegetative reproduction at the "clonal" level. In contrast, a lower reproductive effort on the part of males would leave more energy resources available for increased vegetative reproduction, thus widening the male-biased sex ratio (Lloyd and Webb, 1977).

Lovett Doust and Lovett Doust (1988) suggest that female stems may sequester resources from connected vegetative stems to pay the increased costs of reproduction, resulting in higher mortality and lower survivorship within female "clones". Hancock and Bringhurst (1980) corroborate this, pointing out that since pistillate plants are devoting a higher proportion of their total biomass to sexual reproduction than males (at the expense of root and shoot production), they may suffer higher mortality. Our measurements of stem dieback, however, failed to reveal significant differences between sexes.

SUMMARY AND CONCLUSIONS

Females of the dioecious shrub, *Lindera melissifolia* produce significantly fewer flowers than do the males of the species. This probably entails a selective advantage, since females tend to have a higher resource expenditure per flower due to the energy required for fruit production. Females also produce fewer leaves than males, incurring an even greater disavantage in the absence of photosynthetic structures that could help bear the additional costs of fruiting.

Aside from flower and leaf number, no sexually dimorphic characters were found in this study.

There is lower area coverage by and lower stem density within female "clones", as compared to males. If, indeed, the cost of reproduction is greater for the female than for the male, the deficit in reproductive resource allocation is reflected at the "clonal" level through increased mortality or decreased suvivorship and/or reduced vegetative reproduction.

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DESIGN OF A VISCOMETER USING MAGNETOSTRICTION OF FERROMAGNETIC PROBES

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ABSTRACT

On-line measurement of viscosity of process liquids at process temperature is difficult though industrially very important. A viscometer is designed which can do this up to about 300 °C almost on-line within about 1-8% accuracy except for very viscous liquids like glucose. It uses a ferromagnetic probe designed to mechanically vibrate in the ultrasonic frequency range. An excitation coil sends repeated excitation current pulses to induce mechanical vibration in the probe tip. When placed in a process fluid, the vibration amplitude is damped due to the viscosity of the fluid, and the damped vibration is sensed by Faraday's principle by a sensing coil. The number of pulses per second needed to keep the probe vibrating above a threshold level is directly proportional to the viscosity of the fluid. Necessary calibration was done and the performance tested using several pure liquids as references with known viscosities in the range 0.1 - 2,000 cp at temperatures between −80 and +300 °C.

INTRODUCTION

On-line quality control of process fluids is needed industrially which can be achieved if on-line viscosities of these can be measured at process temperatures without stopping the production (Willard *et al.*, 1985).

Ultrasonic probes may be a better alternative to the conventional static viscosity measurements like using the falling ball or capillary rise methods. In this work, the rate of damping of a vibrating metal tip by the viscous fluid is used to arrive (in about a minute or less) at the viscosity values of the process fluids (Sarkar, 1978). The damped vibration of the ferromagnetic tip is generated by the magnetostriction or piezomagnetic principle (Bozorth, 1951). Therefore, such a viscometer can sample process fluids at temperatures less than the Curie temperature of the ferromagnetic tip.

When a ferromagnet is mechanically stressed, a voltage is generated by magnetostriction principle (Craik *et al.*, 1966). Similarly, when a voltage is applied to a ferromagnet, its dimensions change by the inverse magnetostriction principle. In this study, a current pulse in the exciting coil around the magnetic tip induced a voltage in the tip by Faraday's principle. This voltage caused the probe tip to mechanically change its shape due to the inverse magnetostriction principle mentioned above. Depending on the geometry of the probe, the mechanical stress drove it to vibrate at its fundamental or one of the harmonic frequencies. The vibrating tip eventually got damped due to the viscous drag from the test process fluid. A sensing coil wired around the magnetic tip sensed the amplitude of the damped vibration by Faraday's principle again. Using a level detection circuit in conjunction with a pulse generator, excitation pulses were sent to reexcite the probe tip when its vibration amplitude fell below a preset level. More viscous a fluid was, faster was the damping of the ferromagnetic tip. Pure liquids with known viscosities were used to calibrate the damping rate and convert these to viscosity readings. Unknown viscosities were then read directly by interpolation of these calibration curves corresponding to the damping rates of the tip in those fluids. The consistency with other methods was within 3% at room temperature for almost all the test samples but was off by 12% at 100 °C for glucose.

MATERIALS AND METHODS

The transducer probe consisted of a ferromagnetic strip, two surrounding coils one for converting the mechanical energy to voltage pulses and the other for driving the tip, and a preamplifier stage all encased in steel casing with the tip protruding out for probing the process fluid directly.

Various geometries of the magnetic strip were tested to arrive at the best one offering maximum dimension change with applied voltages for highest sensitivity in the temperature range used. The best geometry with optimum magnetostriction coefficients in transverse direction was an ellipsoidal one with low aspect ratio (Craik *et al.*, 1966). Considering the difficulty and cost involved for such a probe, a moderate substitute for the ellipsoidal geometry, viz., rectangular strips were used. The mechanical vibration with the center of the strip held fixed is at the first harmonic frequency with antinodes at the edges providing the greatest excursion of the probe tip. Typically for 8 cm x 0.2 cm x 0.05 cm strips, this frequency is in the ultrasonic range. The fundamental or the higher harmonic vibrations were avoided since maximum tip displacements give maximum sensitivity. Figure 1 displays a block diagram of the circuitry.

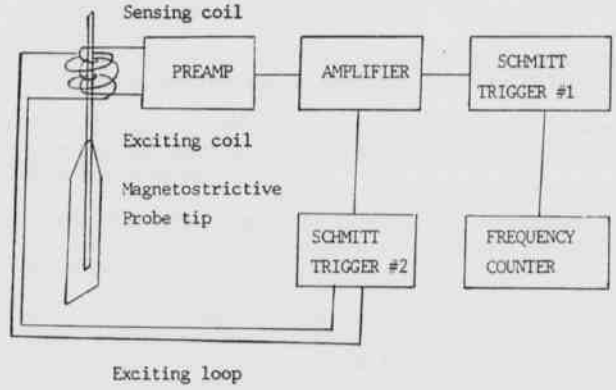

Figure 1. Block diagram showing the viscometer probe and the electronic circuitry for detection of the frequency of damped vibration of the ferromagnetic tip.

The bandwidth of a sharp mechanical disturbance (like a touch on the strip) is infinitely wide and it excites the chosen geometry at its first harmonic frequency f_1 which generates electrical pulses at the same frequency. These pulses are microvolt intensities and at megahertz frequencies. It is better to preamplify these to about one tenth of a volt

in the probe itself to avoid amplification of noise. This was done with 741 operational amplifiers with minimum possible external components housed inside the steel casing.

When the vibrating magnetic strip comes in contact with a viscous medium, the tip vibration is mechanically damped and generates damped microvolt pulses at the same ultrasonic frequency. After amplifying these pulses to about 10 V maximum, they are detected by a pair of Schmitt triggers. The first one detects only the onset of the oscillations and sends a square pulse to a digital counter. The second one detects the tail of the damped oscillations at a preset voltage level and sends the square wave output to the exciting coil around the probe tip. Thus the viscous nature of the process fluid is measured by frequency (damping rate per second) which is linearly proportional to the viscosity of the fluid.

Pure liquids with known viscosities in the range 0.1 cp – 2000 cp were used to calibrate the digital counter readings (Table 1). Eleven calibrating

Table 1. Pure liquids used to calibrate viscometer at 20°C

Reference Liquids	Viscosity(cp)	Counter Reading
Acetaldehyde	0.22	33
Ethyl Acetate	0.46	69
Benzene	0.65	98
Chloroform	0.58	87
Ethyl Alcohol	1.20	228
Aniline	4.40	827
m-Cresol	20.8	4002
Cyclohexanol	68	12650
Olive Oil	84	16017
Rapeseed Oil	163	35403
Glycerin	1490	323005

liquids were used in 3 ranges of viscosity values — first with viscosities less than 1, second with viscosities between 1 and 100, and finally liquids with viscosities more than 100. All 3 calibration curves were linear with different slopes. Unknown viscosities were then directly read by interpolating the calibration curves at the frequency meter readings. Most of the viscosities obtained in this way were within about 1-3% of the standard viscosity values (Weast, 1986) except for glucose which was 12% off from its accepted viscosity value. The frequency meter readings took typically a few seconds (at the lower ranges of viscosities) to at most a minute (for glycerin and glucose) to stabilize and hence can be claimed to be on-line or instantaneous. At temperatures between the room temperature and the Curie point, the voltage pulse amplitudes decreased because the net magnetization decreased with increasing temperature (Kittel, 1986) though the frequency remained unaltered. By manually resetting the Schmitt trigger levels, the viscosity measurements up to about 300°C was possible within 1-12% accuracy using 99.98% nickel probe tips.

RESULTS AND DISCUSSION

Table 2 shows viscosity values obtained for 8 test liquids at 20°C. Note that the disagreements with other methods are less than 3% in the wide range of viscosities covering over three orders of magnitude.

Table 3 reports measurements done using this meter at various temperatures. In the wide temperature range from – 80 to 300°C deviation from the viscosity data obtained by other methods is about 1 to 8%. For glucose it is 12% at 100°C. Note here that the data at both low and high temperatures were collected fast to avoid averaging of temperature through possible nonuniformity of heating and increased

Table 2. Test Results of Viscosity Measurements at 20°C Using Calibration Curves for Ultrasonic Viscometer

Test Liquids	Viscosity Data at 20°C	Measured Viscosity at 20°C (cp)	Difference %
Antimony Disulfide	0.36	0.37	+2.8
Allyl Alcohol	1.36	1.35	-0.7
CCl_4	0.97	0.98	+1.0
Cyclohexene	0.66	0.65	-1.5
Ethylene Glycol	19.9	20.1	+1.0
Sulfuric Acid	25.4	24.8	-3.1
Cottonseed Oil	70.4	72.1	+2.4
Castor Oil	986	976.2	-1.0

Table 3. Viscosity Measurements at Extreme Temperatures

Test Liquids	Operating Temperature	Viscosity at Op. Temp (cp)	Measured Viscosity (cp)	Difference %
Acetone	-80	1.49	1.51	+0.7
	-42.5	0.69	0.68	-1.4
	0	0.40	0.39	-2.5
	+41	0.28	0.29	+3.6
Aniline	0	10.2	9.8	-3.9
	100	0.83	0.84	+1.2
Glucose	100	2.5×10^4	2.8×10^4	+12
Mercury	100	1.24	1.22	-1.6
	150	1.13	1.19	+5.3
	200	1.05	1.10	+4.8
	250	0.99	0.91	-8
	300	0.95	0.88	-7.4

convection at higher temperatures could not be avoided. All of these might have contributed to the observed deviation. Finally, manual adjustment of the Schmitt trigger levels at higher temperatures was difficult and was the prime source of human error. Currently there exists no theory for thermal correction of magnetostriction amplitudes particularly for the ferromagnetic alloys of cobalt, nickel and iron and hence one needs to use empirical corrections for extreme temperatures which has not been done in this study.

For large industrial process operations, stirring is unavoidable. Since mechanical loading will interfere with the vibration frequency, viscosity testing has to be done with an outlet keeping on-line condition but avoiding disturbances from stirring and mixing in the process chamber.

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REPRODUCTIVE PHENOPHASES AND CLUTCH CHARACTERISTICS OF SELECTED ARKANSAS AMPHIBIANS

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ABSTRACT

Seasonal reproductive phenomena in 13 species of salamanders and 16 species of anurans from Arkansas were investigated. Most specimens were collected during a span of 6 years (1985-1990). Clutch characteristics, including mensural and meristic data, were determined from gravid females. In some species, the size of egg masses was also documented. Among the plethodontid salamanders, average clutch size (in parentheses) was greatest in *Eurycea lucifuga* (77.7) and smallest in *Plethodon serratus* (7.0). One of 2 ambystomatid salamanders *(Ambystoma texanum)* averaged 545.4 eggs per clutch; the other species *(Ambystoma tigrinum)* averaged 130.5. *Siren intermedia nettingi* (one of 3 large salamanders examined) had the greatest mean clutch size (851.3). Among anurans, *Rana catesbeiana* had the largest clutch size and mass (43,073 eggs and 55.9 g), whereas clutches of *Acris crepitans blanchardi* averaged the smallest (264.1 eggs and 0.1382 g). Multiple clutch production may be the rule in some amphibians (e.g., *Desmognathus brimleyorum, A. c. blanchardi, Pseudacris triseriata feriarum,* and *P. streckeri streckeri*); however, partial clutch deposition remains a possibility in these species. By knowing the synchrony between male and female reproductive cycles, a clarification of the onset, timing, and duration of reproductive phenophases (e.g., courtship, breeding, egg laying, etc.) was documented in many species.

INTRODUCTION

Reproductive phenology is the study of the seasonality of reproductive events and represents a suite of life history phenomena often neglected during field studies on amphibians. For many species, the seasonal timing of reproduction is determined largely by and adjusted to fit within recurring climatic episodes; Dowling (1974) and Mitchell (1979) provided reviews on the subject of phenology and its application in herpetology. Comparative phenological data related to the annual and seasonal timing of amphibian reproductive phenophases (i.e., the timing and duration of courtship activities, mating, egg laying, hatching, and metamorphosis) are generally lacking in many geographic areas in the United States; this is especially true for Arkansas. Collecting phenophase data is perhaps the simplest of tasks related to field investigations on breeding anurans. Geographic variation in reproductive phenophases exists; yet, few studies have addressed this topic satisfactorily on a regional or statewide basis (for a notable exception, see Dundee and Rossman, 1989).

In many salamander species, a precise determination of the timing of mating activities can only be accomplished through the histological examination of the female spermatheca for the presence of spermatozoa (e.g., Ireland, 1976; Trauth, 1983, 1984); nevertheless, clutch characteristics (i.e., the presence of enlarged ovarian follicles or total mass of the ovaries) can also provide valuable information as to the onset and duration of the reproductive season as well as to information on clutch size. Nesting phenophases in salamanders yield data on oviposition, embryonic development, and hatching success and can contribute a better assessment of overall fecundity in populations (Juterbock, 1986). Other studies have shown that seasonal variation in anuran reproductive phenologies insures a competitive advantage in species that breed early (see Alford, 1989).

In the present study, we provide data on the reproductive phenologies of 29 species of amphibians from Arkansas. Although our survey does not include every possible reproductive phenomenon in each species, our primary objectives were to document poorly known species and to analyze clutch characteristics when gravid females were available.

MATERIALS AND METHODS

Most of the amphibians examined in this study were collected over a six-year period (1985-1990). One notable exception was a span of 10 years for *Desmognathus brimleyorum* (i.e., 1980-1989). Nearly all specimens were processed within 24 hr. after capture. Snout-vent length (SVL) was measured to the nearest 0.1 mm. Individuals were killed in a 20% chloretone solution, fixed in 10% formalin, and preserved in 70% ethanol. Egg masses and egg clutches were placed directly into 10% formalin for storage. With few exceptions, quantitative data on clutch parameters were gathered following techniques discussed elsewhere (Trauth, 1989a). In general, clutch size was calculated by counting all yolked ovarian follicles in each female or by an estimation of clutch size (see Trauth, 1989a). Standard errors (± 2SE) are given along with sample means when the sample size was greater than 10. All specimens (including adults, larvae, eggs, and ovarian follicles) are deposited in the Arkansas State University Museum of Zoology. Standard common names and current scientific names follow, in most cases, Collins (1990).

RESULTS AND DISCUSSION

ORDER CAUDATA
Family Plethodontidae

Three species of dusky salamanders are known from Arkansas. The biology of the Ouachita dusky salamander, *Desmognathus brimleyorum,* was reviewed by Means (1974); yet, little has been published on its reproduction in Arkansas (for recent data, see Chaney, 1958; Health

et al., 1986; Trauth, 1988). This species was extensively collected from Rich Mountain (an east-to-west running mountain in Polk County) in western Arkansas. Only females with a SVL greater than 62 mm possessed yolked ovarian follicles; the seasonal distribution of gravid females and the average size of their ova are shown in Fig. 1. Females of this species deposit their egg clutches during the summer months (Trauth, 1988); however, data shown in Fig. 1. suggest that oviposition can

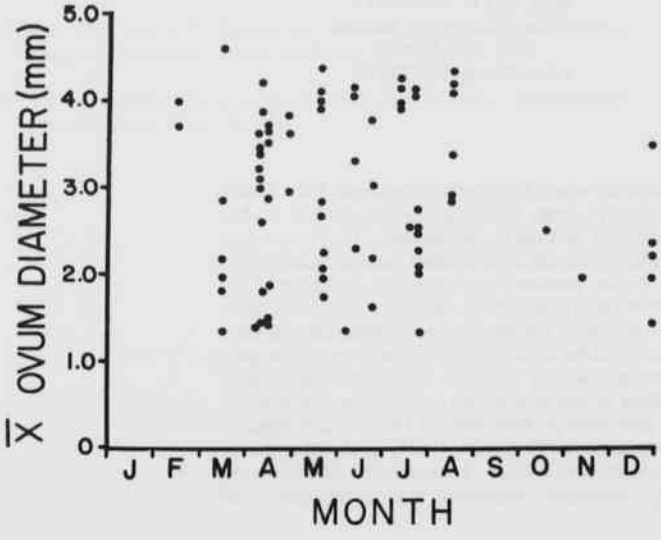

Figure 1. Seasonal distribution of yolked ovarian follicles and their average ovum diameter in *Desmognathus brimleyorum*.

occur any time from March until September. Larger (older) females appear to ovipost earlier than smaller (younger) females; this is supported by the fact that some large females in March and April bear yolked follicles near the presumed size at ovulation (4.0-4.5 mm in diameter). During the same time period, other large females contain regressed ovaries with ova just beginning vitellogenesis (1.3-1.5 mm in diameter); this is a condition suggestive of either a pre- or postreproductive stage. Clutch size ($\bar{x}$ = 26.7 ± 1.53; n = 76; r = 0.36; P < 0.05) showed a significant positive correlation with SVL (Fig. 2), although vitellogenesis can vary in response to environmental conditions or food availability (Tilley, 1977). The discovery of nesting females during the late winter or early spring is essential before a biannual reproductive cycle can be confirmed (Juterbock, 1986). Yet, size of larvae taken during the year from Rich Mountain indicates a late winter-early spring ovipositional period. For example, in December, one larva measured 19 mm SVL. Four larvae in February ranged from 17 to 21 mm SVL ($\bar{x}$ = 19.5); in mid-March, 2 larvae were 18 mm SVL. By early April a series of 9 (recently hatched?) larvae ranged from 16 to 18 mm SVL ($\bar{x}$ = 17.0), and in late April a series of 8 larvae ranged from 18 to 24 mm SVL ($\bar{x}$ = 21.4). In early June, small larvae (18-20 mm SVL) were still being captured. By mid-August, transformation had occurred, and the smallest unsexed juveniles ranged from 27-31 mm SVL.

Populations of the southern dusky salamander, *D. auriculatus,* occur in several counties in southern Arkansas. Aspects of the life history of this species in Arkansas have not been elucidated. A single gravid female (57 mm SVL) and one immature female (47 mm SVL) were collected on 17 February 1990 from Ouachita County. Clutch size was 32, and ovum diameter averaged 2.93 mm. Four additional gravid females were collected from Ouachita County near Tates Bluff on 3 April 1990; these females averaged 37.25 yolked ova (range 30-41). In addition, these ova ranged from 1.75 to 2.49 mm in average diameter. Thus, a grand mean clutch size of 36.2 was found in females ranging from 54 to 66 mm SVL. One larva was collected 17 February 1990 and measured 28 mm SVL. This body length is much greater than any *D. brimleyorum* larvae collected at approximately the same time of the year.

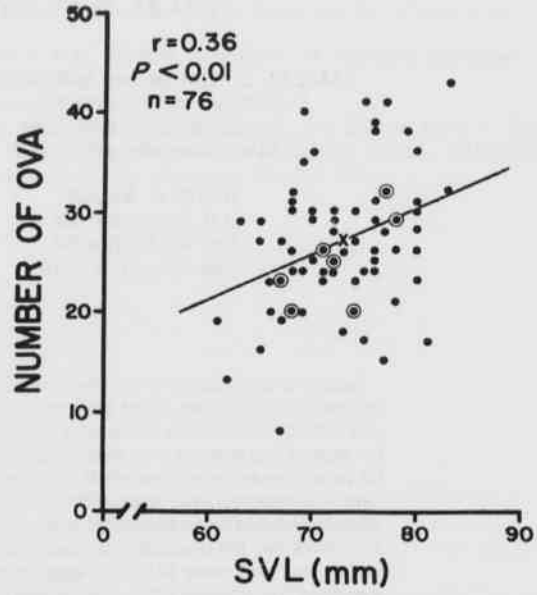

Figure 2. Relationship between clutch size and SVL in *Desmognathus brimleyorum*. Circles symbols represent two records; the regression equation is Y = −7.7860 + 0.4753X. Mean values for X and Y coordinates — X.

Although the spotted dusky salamander, *D. fuscus conanti,* has been collected from spring seepages along the eastern slopes of Crowley's Ridge (Means, 1974; Nickerson *et al.*, 1979; Smith, 1960b), no individuals were collected during many attempts over the last 5 years. The reproductive biology of this species has not been determined in Arkansas populations.

The distribution of the cave salamander, *Eurycea lucifuga,* is restricted to the Ozark Mountains in Arkansas. The reproductive biology of this species is poorly known for Arkansas population (Smith, 1964). Average clutch size was 77.7 (range 60-120) in 11 gravid females. Yolk deposition begins in February and continues into August. The smallest gravid female had a SVL of 54 mm (the largest, 67 mm). Most larvae of *E. lucifuga* metamorphose in less than 1 year (Rudolph, 1978); however, some populations require more than 1 year. For example, most larvae transform at around 25 mm SVL (Rudolph, 1978) sometime between July and October. We found larvae averaging 31.6 mm SLV (range 29-37) in late October and others averaging 37.2 mm SLV (range 30-40) in early January. The smallest transformed individual was collected in mid-February and measured 30 mm SVL; transformed individuals in late May were 36 mm SVL.

The graybellied salamander, *Eurycea multiplicata griseogaster,* inhabits aquatic habitats associated with caves and spring-fed streams within the Ozark Mountains of Arkansas (Ireland, 1976). Dundee (1965) pointed out that many populations of *E. m. griseogaster* within the Salem Plateau of northcentral and northeastern Arkansas are neotenic. A single neotenic population in Marion County was studied during the 1989-1990 calendar years. Two gravid neotenic females were collected from Chapman Spring (near Lakeway) on 3 September 1989; clutch size and average ovum diameter for one (36 mm SVL) were 8 and 1.93 mm and for the other (38 mm SVL), 13 and 2.15 mm. Upon returning to the spring on 21 October, all 7 adult females collected (31-41 mm SVL) were postreproductive. Three egg clutches of 8, 10, and 14 eggs were discovered beneath several layers of small rocks within the spring's flow just downstream from the spring's mouth. The pregastrular embryos averaged 2.36 mm in diameter (2.01-2.61), whereas the averge diameter of the total egg capsule was 5.80 mm (5.37-6.09). The jelly capsules were similar to those described by Spotila and Ireland (1970) for a non-neotenic population. Larvae were found at the spring on 16 March 1990 and averaged 15.0 in SVL. Average adult SVL in late Oc-

tober was 36.4 mm (30-41; n = 14) and 33.8 mm (29-37; n = 11) in mid-March 1990.

Little life history information exists for the many-ribbed salamander. *E. m. multiplicata,* a species largely confined to the Ouachita Mountains in Arkansas. No gravid females were found in any of the samples collected from late December to mid-March. In contrast, all 3 populations of *E. m. griseogaster* studied by Ireland (1976) had females with enlarged ovarian follicles during this time of the year.

The Oklahoma salamander, *Eurycea tynerensis,* is a larviform species that is restricted to the western half of Benton County in extreme northwestern Arkansas (Cline *et al.,* 1989). Reproduction in Arkansas populations has not been published. We found gravid females on 18 May and 12 November 1989. Clutch size in 3 females ranged from 1 to 11 eggs ($\bar{x}$ = 6.67). The presence of females with regressed ovaries in addition to females with enlarged ova in May suggests that oviposition occurs in the summer. The single gravid female collected in November possessed enlarged oviducts which indicates the possibility that multiple clutches are produced by this species.

Reproduction in the four-toed salamander, *Hemidactylium scutatum,* has not been published for Arkansas populations. Although known from the Ozark Mountains of Arkansas (Trauth and Caldwell, 1986), our samples primarily came from sites in Garland and Montgomery counties of the Ouachita Mountains. Road collecting was conducted at night during rainstorms and yielded a disproportionately large number of gravid females (38) compared to adult males (4). The relationship between clutch size and body size is shown in Fig. 3; average clutch size in 31 females was 42.41 ± 2.78 (27-57). Vitellogenic ova were present in females collected from October through mid-March. Several gravid females collected on 17 February 1990 were placed in an aquarium supplied with sphagnum moss; three females laid communal egg clutches by 21 February. Hatching began in 2 egg clutches 23 days later (16 March). Brooding behavior as described by Harris and gill (1980) was observed.

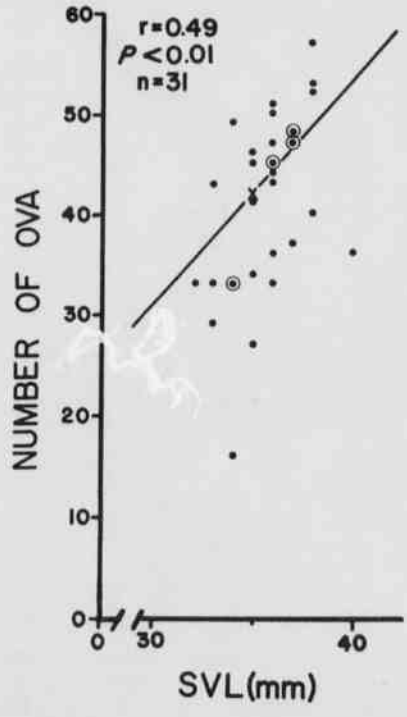

Figure 3. Relationship between clutch size and SVL in *Hemidactylium scutatum.* Circles symbols represent two records; the regression equation is Y = −29.4500 + 2.0890X.

The southern redback salamander, *Plethodon serratus,* is the smallest of 6 species of *Plethodon* that are known to occur in Arkansas. Reproduction in this species was examined from samples taken from Rich Mountain. Yolk deposition begins as early as January; ova reach a maximum diameter of approximately 3.0 mm by late May. The average clutch size of 7.04 ± 0.41 (5-9; n = 22) was greater than an average of 5.5 for this species in Georgia (Camp, 1988).

The reproductive biology of Arkansas populations of the grotto salamander, *Typhlotriton spelaeus,* a troglobitic species that inhabits caves and springs in the Ozark Mountains, has received little attention. The most detailed life history account was conducted by Brandon (1971) in Missouri. We examined clutch size, ovum diameter, and other reproductive traits from museum specimens in the ASUMZ collection and the Northeast Louisiana University collection. The largest ova ($\bar{x}$ = 3.10 mm) were observed in a female collected in early June. Enlarged vitellogenic ova were present in most females from April through August. Smith (1960a) found egg clutches in January. We found larvae averaging 20.5 mm SVL (18-24; n = 10) in mid-April; others at this time were as large as 45 mm SVL and were nearing metamorphic size. This species requires over one year to transform (Rudolph, 1978; Smith, 1960a).

Family Ambystomatidae

Aspects of the reproductive biology of the smallmouth salamander, *Ambystoma texanum,* have been reported in this species throughout its range (Anderson, 1967). Plummer (1977) found that clutch size was correlated with SVL in Kansas specimens. In Arkansas specimens examined (n = 8), average clutch size was 545.38 (250-813); clutch size was negatively correlated (r = −0.05) with SVL. Smallmouth salamanders partition their clutches into many small egg clusters which they attach to vegetation in temporary pools or drainage ditches. Egg mass size averaged 12.62 ± 1.50 (5-22; n = 34); egg masses are generally laid from late January to mid-April.

Until recently, few locality records had been published for the eastern tiger salamander, *Ambystoma tigrinum tigrinum,* in Arkansas (Butterfield and Marks, 1989; Dowling, 1957; Trauth *et al.,* 1987). Since March, 1987, a total of 16 adult salamanders has been collected from 4 sites in the northeastern Ozark Mountains (Fulton, Izard, and Randolph counties). Females with oviductal eggs were collected 6 January and 17 February, 1989. All females collected in March were postreproductive. On 4 February 1990, egg masses were discovered in a stock pond near Band Mill (Izard County); 2 egg masses of 96 and 165 eggs were recorded. Length of incubation of eggs (in 1990) was estimated to be 40 to 45 days. By mid-March, larvae had attained an average SVL of 18.0 mm; by mid-April, larvae averaged 33.25 mm SVL, and in mid-June, 1989, larvae had reached 55.0 mm SVL. All larvae had transformed by mid-July, 1989.

Family Amphiumidae

Reproduction in the three-toed amphiuma, *Amphiuma tridactylum,* has been studied little in Arkansas since the work of Hay (1888) in Pulaski County. Cagle (1948) found an average clutch size of 98.0 in 26 females from Louisiana. Only 2 gravid females were examined in our study; average clutch size was 103.5 (80 and 127). Vitellogenic ova in these 2 females collected 24 March 1989 (Greene County) averaged 4.11 and 4.22 mm in diameter and were similar to the size range of 3.5-4.5 mm given by Cagle for March specimens.

Family Proteidae

The life history of the Red River mudpuppy, *Necturus maculosus louisianensis,* is best known from studies in Louisiana (Cagle, 1954; Shoop, 1965). A total of 9 gravid females from Arkansas yielded an average clutch size of 106.5 (48-174). The smallest female possessing yolked ovarian follicles was 156 mm SVL; the largest was 235 mm SVL. Shoop (1965) reported an average clutch size of 54.2 (31-91) in 48 females; in addition, the largest gravid female he examined was 180 mm SVL. In our sample, the largest ova ranged from 4.35-5.22 mm in diameter and were measured from females taken from the St. Francis River (Craighead County) in July. Ovum diameter in March specimens from the same site was 4.54-5.19 mm.

Reproductive Phenophases and Clutch Characteristics of Selected Arkansas Amphibians

Family Sirenidae

The type locality for the western lesser siren, *Siren intermedia nettingi,* is near Imboden in Lawrence County (Goin, 1942). Egg laying was observed by Noble and Marshall (1932) near Imboden, and they presented drawings of larval development which showed stages from hatching to 51 days old. Noble and Marshall (op. cit.) also provided clutch sizes of 260, 299, and 555 eggs. Our data on clutch size shown in Fig. 4 are from specimens collected in Clay and Greene counties. Average clutch size was 851.37 (98-1506; n = 8). Ovulation was occurring in 1 female collected 31 March 1968; this individual had an average ovum diameter of 2.94 mm. Size-age class data indicate that females reproduce at 2 years of age. The smallest female to possess yolked ovarian follicles was 165 mm SVL. Older females (> 2 years) produce much larger clutches than younger females; clutch size is significantly correlated with SVL (Fig. 4).

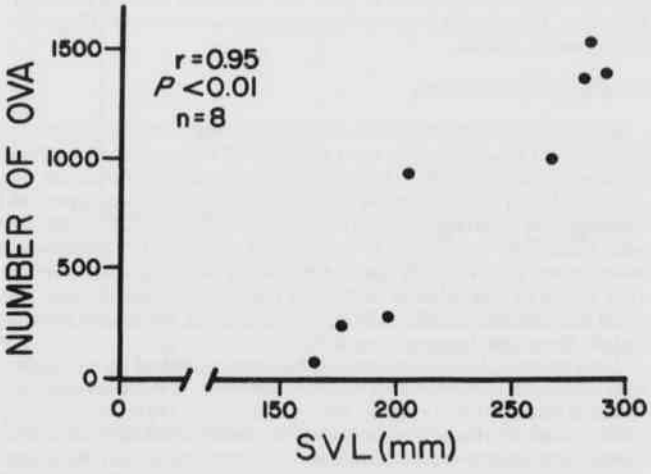

Figure 4. Relationship between clutch size and SVL in *Siren intermedia nettingi.*

ORDER ANURA
Family Bufonidae

Reproduction in the dwarf American toad, *Bufo americanus charlesmithi,* and Fowler's toad, *B. woodhousii fowleri,* has not been studied in Arkansas. Breeding choruses of *B. a. charlesmithi* generally begin in early March, slightly before calling in *B. w. fowleri.* Breeding in both species reaches a peak from late April to early May. Clutch size in both species showed a significant positive correlation with SVL (Fig. 5). Average clutch size in *B. a. charlesmithi* (4701.0 ± 2553.0; range = 1840-13,982; n = 10) is less than that of *B. w. fowleri* (8175.7 ± 1978.4; range = 3067-15,618; n = 14). Transforming *B. w. fowleri* were observed in Logan County on 7 June 1989; individuals had well-developed hind legs and an averaged SVL of 14.0 mm. Recently-hatched tadpoles of *B. a. charlesmithi* were found in Salado Creek (Independence County) on 26 July 1990; larvae at this time of the summer would indicate an extended breeding season or multiple clutch production in this species.

Family Hylidae

Members of the family Hylidae are among the earliest breeding anurans that occur in Arkansas. The northern cricket frog, *Acris crepitans crepitans,* is predominately found in the southeastern portion of the state, whereas Blanchard's cricket frog, *A. c. blanchardi,* is mostly confined to the Interior Highlands. Both forms are active

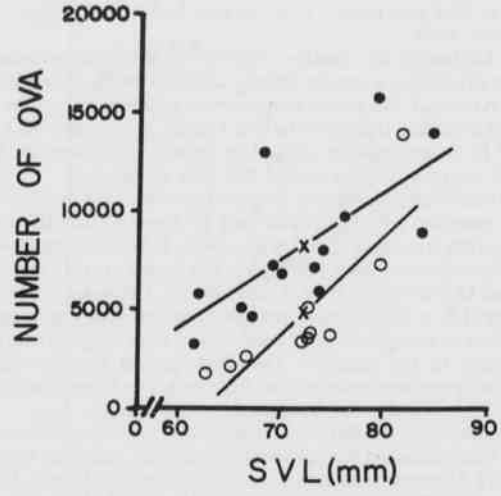

Figure 5. Relationship between clutch size and SVL in *Bufo americanus charlesmithi* (open symbols) and *Bufo woodhousi fowleri* (closed symbols). For *B. a. charlesmithi,* r = 0.82; $P<0.001$; n = 10; the regression equation is Y = −32083.6 + 510.9X. For *B. w. fowleri,* r = 0.68; $P<0.001$; n = 14; the regression equation is Y = −16652.7 + 345.8X.

throughout the year, but the seasonal development of ova in *A. c. blanchardi* spans from mid-April to late July. Based upon the simultaneous presence of vitellogenic ova (in the absence of oviductal eggs) and the presence of ovarian scars (corpora lutea) in several females, it was concluded that female *A. c. blanchardi* may produce multiple clutches or may deposit partial clutches during a breeding season. Developing ova that contribute to additional clutches were found in females in May and July. Clutch characteristics for *A. c. blanchardi* include an average clutch size of 266.11 ± 54.83 (174-431; n = 9) and 127.0 (120 and 134) for 2 specimens producing additional clutches. In 3 *A. c. crepitans,* average clutch size was 258.0 (231-298). Average ovarian mass in *A. c. blanchardi* was 0.0542 g (0.0286-0.1288). In early June, *A. c. blanchardi* tadpoles reach a maximum total length of 36 mm; transforming individuals were found at Morrilton (Conway County) in mid-July.

Of the 3 species of *Hyla* (treefrogs) examined during this study *H. versicolor,* the gray treefrog, began yolk deposition prior to entering overwintering retreats (Fig. 6; September specimen). Because of the lack of gravid females available for study, the timing of yolk deposition in the other species remains unknown. Clutch size in 6 gravid females of the green treefrog, *H. cinerea,* averaged 2152.0 (1348-3946). This average appears somewhat inflated mainly because of the high number of ova in 1 specimen (55 mm SVL). By excluding this female, a revised mean of 1793.2 (1348-2537) was calculated. Nevertheless, these averages for *H. cinera* greatly exceed the estimated 500-1000 eggs reported for this species in southern Illinois (Garton and Brandon, 1975). In *H. versicolor,* calling males were observed as early as 12 March 1990 in the Russellville area (Pope County), on 8 May 1989 near Toad Suck Ferry Lock & Dam (Faulkner County), on 18 June 1989 near Bull Shoals Lake (Marion County), and on 27 June 1987 in Morrilton. Both *H. versicolor* and *H. chrysoscelis* (Cope's gray treefrog) were heard calling syntopically 12.8 km W Mayflower (Faulkner County) on 1 June 1989. *Hyla chrysoscelis* was also heard calling on 17 July 1989 near Columbus (Hempstead County) and on 2 September 1989 near Petit Jean State Park (Perry County). The latter calling episode for *H. chrysoscelis* occurred outside the normal reproductive season and, in this instance, is referred to as a "rain call." Average clutch size in *H. versicolor* and *H. chrysoscelis* was 2070.5 (1288-2604; n = 10) and 3401.0 (1086-4797; n = 4), respectively. Ritke *et al.* (1990) found an average clutch size of 2060 for *H. chrysoscelis* from western Tennessee; they also noted multiple clutch production in this species. Transforming *H. versicolor* tadpoles were observed on 14 June 1989 in Izard County; they averag-

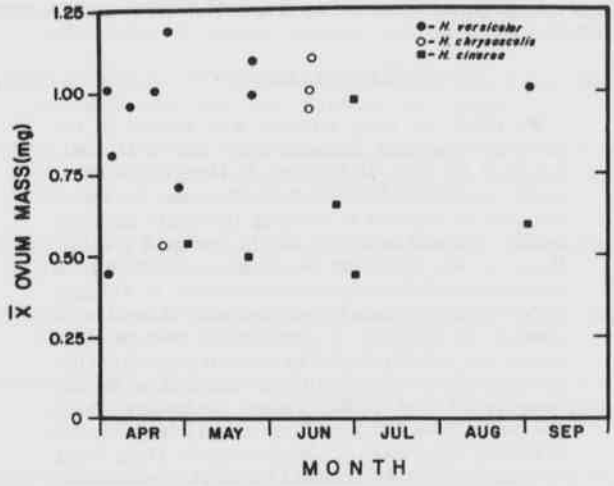

Figure 6. Relationship between average ovum mass and time of year in three species of *Hyla*.

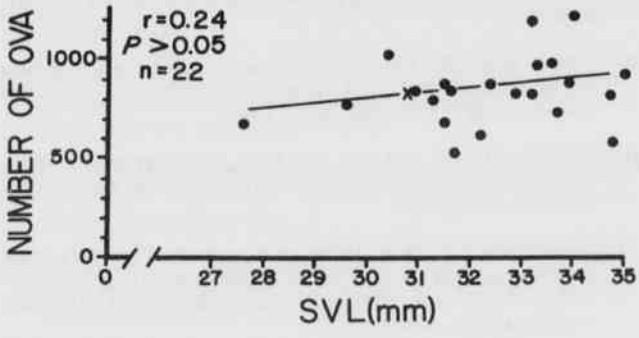

Figure 7. Relationship between clutch size and SVL in *Pseudacris crucifer*. The regression equation is Y = 88.32 + 24.23X.

ed 19.5 mm SVL (19-20), whereas the same species was transforming on 9 August 1989 in Morrilton at an average SVL of 17 mm. Transforming tadpoles of *H. chrysoscelis* were found in Drew County on 23 June 1989 and measured from 15 to 16 mm SVL ($\bar{x}$ = 15.4).

Within the genus *Pseudacris* (chorus frogs), breeding colonies may be heard as early as mid-January and extend to late April. Clutch size in the spring peeper, *P. crucifer* (formerly *Hyla crucifer*), is shown as a function of body size in Fig. 7. The correlation between these 2 variables was not significant. The average clutch size (n = 22) was 846.64 ± 58.38 (505-1201), and the average ovarian mass was 0.57 g ± 0.11 (0.22-1.52).

Reproductive activity in the uplands chorus frog, *P. triseriata feriarum*, also begins in mid-January. Duellman and Trueb (1986) indicated that *P. triseriata* can produce at least 2 egg clutches per breeding season. Our data (Fig. 8) support the possibility of multiple clutches; however, the deposition of partial clutches spread over the reproductive season cannot be excluded. Average clutch size in *P. t. feriarum* based solely upon enlarged vitellogenic ova in nonamplectant females with no oviductal eggs was 1002.5 ± 268.87 (445-1380) for February (n

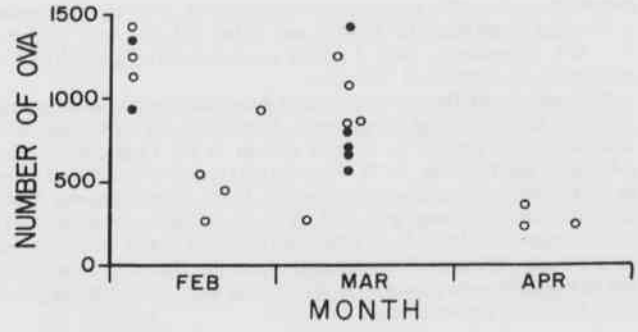

Figure 8. Variation is clutch size during the reproductive season in *Pseudacris triseriata feriarum*. Clutch size is based on ovarian counts with no concomitant oviductal eggs (open symbols) and on both ovarian counts and concomitant oviductal eggs (closed symbols).

= 6), 857.5 ± 198.06 (555-1218) for March (n = 6), and 207 ova for a lone female in April. The grand mean clutch size for 13 specimens was 874.38 ± 188.5.

Strecker's chorus frog, *P. streckeri streckeri*, is largely restricted to sandy habitats along the Arkansas River from Faulkner to Sebastian County in Arkansas. Breeding choruses were recorded on 16 February 1990 near Morrilton, on 12 March 1990 at Dardanelle (Yell County), and again near Morrilton on 3 April 1988. Average clutch size in 3 gravid females collected 3 April 1988 was 440.67 (372-503). Butterfield *et al.* (1989) found that clutch size in *P. s. illinoensis* in northeastern Arkansas ranged from 148 to 1012 ($\bar{x}$ = 467.56). The relatively low value for the upper range limit in *P. s. streckeri* may indicate the deposition of multiple and/or partial clutches. Average ovarian mass of the 3 specimens was 0.1923 g (0.1325-0.2211). Transforming *P. s. streckeri* were collected 9 May 1989 from Holla Bend National Wildlife Refuge (Pope County) with an average SVL of 17.3 mm (16-19; n = 6); at Dardanelle on 13 April 1990, transforming froglets averaged 24.0 mm SVL (22-25; n = 4).

Family Ranidae

There are 6 species of ranid frogs currently found in Arkansas (Conant, 1975). Two of these (*Rana areolata* and *R. clamitans*) are represented by 2 subspecies. Little reproductive information has been published on 4 of these species; however, the reproductive biology of *R. sphenocephala* (Trauth, 1989a) and *R. sylvatica* (Trauth *et al.*, 1989b) has been investigated. The distribution of the northern crayfish frog, *R. a. circulosa*, is poorly known in Arkansas, although specimens are occasionally found in the Arkansas River Valley as well as in the northeastern corner of the state. A total of 11 specimens (9 males and 2 females) was available for study. Calling males have been observed from late February to early April. A clutch size of 2233 was counted from a gravid female 66.8 mm SVL.

The bullfrog, *R. catesbeiana*, is commonly found throughout Arkansas. The smallest female to contain vitellogenic ova was 113 mm SVL. This size is slightly smaller than that reported for Missouri specimens (see data in Bury and Whelan, 1984). Estimated clutch size ranged from 12,756 in the above specimen to 43,073 in the largest female (176 mm SVL). Average clutch size in 7 females was 22,944.28. Clutch mass varied greatly among 10 females; of the 7 with yolked ovarian follicles, over a ten-fold difference (4.86-55.91 g) in ovarian mass was noted. Bullfrog egg masses were observed in Lonoke County on 15 May 1990.

The bronze frog, *R. c. clamitans*, and the green frog, *R. c. melanota*, have an Arkansas distribution similar to cricket frogs (mentioned earlier) with *R. c. clamitans* found generally in the south and east and *R. c.*

melanota in the north and west (Conant, 1975). Average clutch size in 2 bronze frogs was 5327.0 (4924 and 5730) with SVL's of 73.8 and 72.7 mm, respectively. Only 1 gravid green frog (67.9 mm SVL) was examined; she contained 2851 ova.

Although found throughout most of Arkansas, the pickerel frog, *R. palustris,* is encountered infrequently; individuals are most commonly observed in or around caves and springs in the Ozark Mountains (McDaniel and Gardner, 1977). They are also found in abandoned mines in the Ouachita Mountains (Heath *et al.,* 1986). Clutch size was found to significantly increase with SVL (Fig. 9); average clutch size in 14 females was 1759.59 ± 314.37 (960-2943). Calling males were observed on 8 March 1990 near Possum Grape (Jackson County). Transforming individuals were observed from 12 June to 24 June 1990 in ponds near Bethesda (Independence County).

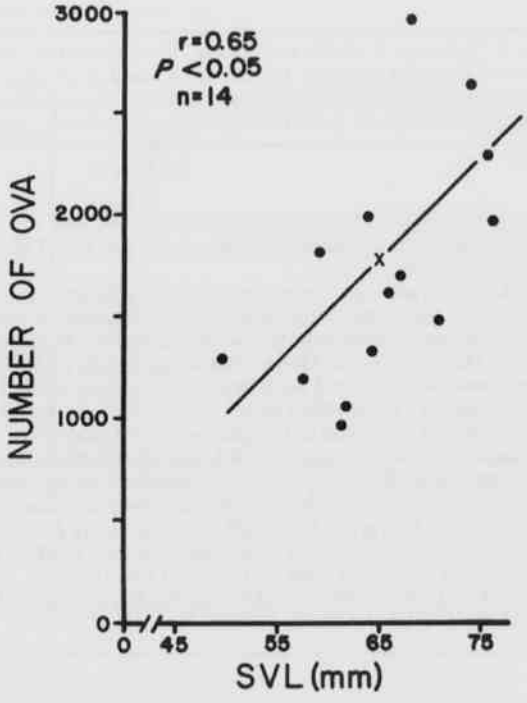

Figure 9. Relationship between clutch size and SVL in *Rana palustris.* The regression equation is Y = −1586.34 + 51.09X.

Family Pelobatidae

The annual breeding cycle of most species of spadefoot toads is largely aseasonal and characteristically occurs during or following heavy rainfall. In northeastern Arkansas, breeding activity of the eastern spadefoot, *Scaphiopus holbrookii holbrookii,* was recorded on 14 March 1986 (Clay County), 28 March 1989 (Clay County), and 14 February 1990 (Craighead County). Clutch size averaged 3838.0 (3522-4469) in 3 females (64.3-65.9 mm SVL), and average ovarian mass was 3.78 g (2.93-4.89). In Hurter's spadefoot, *S. h. hurterii,* breeding may begin in mid-to-late March. Clutch characteristics of 8 gravid females (53.4-62.1 mm SVL) collected 1 April 1988 within the city limits of Dardanelle included an average clutch size of 2494.75 (1961-4847) and an average ovarian mass of 2.14 g (1.29-6.49). Larvae of *S. h. hurterii* were observed at the above site on 8 April 1989 and at a site near Monnie Springs (Pulaski County) on the same date. A breeding colony was located near White Oak Lake (Ouachita County) on 3 June 1990.

The plains spadefoot, *Scaphiopus bombifrons,* is known from only 2 localities in Arkansas (Plummer and Turnipseed, 1982; Trauth *et al.,* 1989a), and both are found within the Arkansas River Valley. Breeding activity has been recorded in the months of April (Trauth *et al.,* 1989a), May (Trauth, 1989b), and June (Plummer and Turnipseed, 1982). Clutch size of a single gravid female collected near Morrilton on 8 May 1989 was 1697.

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ANALYSIS OF THE FALL AND WINTER DIET OF THE BOBCAT IN EASTERN ARKANSAS

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ABSTRACT

Food habits of the bobcat *(Felis rufus)* in eastern Arkansas were examined based on stomach contents of 148 specimens. Rabbits (*Sylvilagus floridanus* and *S. aquaticus*) were the primary food source for males, females, and kittens. Rice rats *(Oryzomys palustris)*, nutria *(Myocastor coypus)*, and several species of waterfowl are first reported as food of bobcats in Arkansas. Cotton rats *(Sigmodon hispidus)* and muskrats *(Ondatra zibethica)* were more common in bobcat diets in eastern versus western Arkansas. Adult males did not use smaller prey but this food source was common in kittens; females were intermediate in their use of smaller prey.

INTRODUCTION

Many of the published studies of bobcat *(Felis rufus)* food habits do not treat sexes and ages independently, and generally those that do find little or no difference between these groups (Progulske, 1955; Korschgen, 1957; Gashwiler *et al.*, 1960; Kight, 1962; Bailey, 1972; Hall, 1973; Miller, 1980; Storey *et al.*, 1982). Differences between sexes or ages have, however, been documented (Fritts and Sealander, 1978; Litvaitis *et al.*, 1986) but the cause of the differences is still debated. A study was initiated in eastern Arkansas to examine the nature of prey consumed by bobcats and to add insight on the potential causes of any difference between sexes or between age classes.

MATERIALS AND METHODS

Stomachs were removed from carcasses of bobcats collected in eastern Arkansas during December-January trapping seasons of 1979 - 1981 and categorized as distended, half full, or empty. Procedures of food habit analyses were as described by Korschgen (1980). Diagnostic materials such as hair, bones, teeth, beaks, feet, and feathers were recovered for identification and enumeration. Frequency of occurrence was based on the total number of individuals of a prey taxon consumed rather than on the number of stomachs containing the prey. Identification was based on comparison with vertebrate collections housed at Arkansas State University (ASUMZ), a reference collection of dorsal guard hair, and several keys (Mathiak, 1938; Mayer, 1952; Moore *et al.*, 1974; Tumlison, 1983a). The minimum number of individuals of each prey taxon was estimated from conservative interpretation of prey fragments (Rotenberry, 1980; King, 1981).

Trapped bobcats tend to ingest almost anything within their reach (Fritts, 1973); therefore trap debris (mud, feces, plant parts, rocks) was not included in the analysis. Food habits data were recorded by percent occurrence, but volumetric analysis was not attempted due to bias. For example, variation in time between capture and death causes variation in the degree of digestion, affecting validity of volumetric analyses. An alternative approach used to examine diet based on consumed biomass was derived using "standard" weights of prey taxa acquired from literature sources (Tumlison, 1983b). The standard weight was the mean expected weight of a prey taxon. Yoakum (1965) noted that bobcats would ingest the entire biomass of a prey item up to ¾ the size of a jackrabbit *(Lepus californicus)*. This information was used to estimate a critical maximum consumable weight of 2025 g. We used the standard weight, with the size limitation, in lieu of volumetric data because it is thought to depict more adequately the importance of a food item. This approach will theoretically over-estimate the relative importance of some foods. For example, when two rabbits are found but their combined volume could not have been consumed, rabbits may be favored in the analysis. Only one rabbit usually was encountered, therefore the effect of this problem was minimal. Prey taxa weighing more than 2025 g were treated at this critical limit.

Prey taxa encountered in dietary analyses are often more indicative of availability than of preference, thus prey use was further analyzed according to size classes. Mammals were segregated into categories of small (< 400 g), medium (401 - 1000 g), and large (> 1000 g) and birds into small (< 500 g) or large (> 500 g). Analysis of prey size selection provides better insight into the meaning of the frequency distribution of food taxa. Because rabbits are apparently of near optimal size and have been identified as primary food items in many previous studies (Fritts, 1973; Hall, 1973; Bailey, 1979), they were treated separately from other members of their size class.

Analyses were conducted to discern dietary differences between sexes (adults only) and between age groups (kittens and adult females or adult males). Kittens may have food habits more similar to females because kittens remain with their mothers until fall or winter (Hamilton, 1942; Erickson, 1955). This possibility was evaluated by contingency table analysis (Sokal and Rohlf, 1981) and with the Sorenson similarity coefficient (Korschgen, 1980). Because kittens in our sample were about half the size of adults, and therefore had less gastric capacity, the critical consumable weight was treated at one-half the value of adults.

RESULTS

A total of 148 stomachs was obtained. Of these, 33 (22.3%) contained no identifiable remains. The remaining 115 (77.7%) contained remains ranging from a few hairs to entire undigested prey. The number of items recovered from individual stomachs averaged 1.5 (range 1-4). One prey item occurred in 74 stomachs, 2 in 32, 3 in 6, and 4 in 3. Stomachs with 3 or more items consistently contained smaller sized taxa (< 300 g). Stomachs at least half full occurred in 40.5% of the sample. Food items were 82.0% mammal, 17.4% bird, and 0.6% fish. Of the mammalian prey, rabbits (*Sylvilagus floridanus* and *S. aquaticus*) were the primary items by frequency and estimated weight (Tables 1-3). Small mammals were the second most important group by occurrence, but were least important by weight. Cotton rats *(Sigmodon hispidus)* and rice rats *(Oryzomys palustris)* comprised 69.0% of this group. Larger mammalian food items, third in importance by occurrence but second by weight, were dominated by deer *(Odocoileus virginianus)* and muskrat *(Ondatra zibethicus)*, together totalling 74.0% of the items in the group. The medium size class, represented by squirrels, was the least impor-

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tant mammalian class by occurrence and third by weight.

Small birds were twice as important as large birds by occurrence, but large birds were about 6 times as important by weight. A total of ten taxa of small birds were identified; most of the larger birds were waterfowl (Tables 1-3).

Table 1. Prey recovered from stomachs of male bobcats from eastern Arkansas, 1978-79 through 1980-81.

Prey	Freq. of Occurrence	% Occurrence	Estimated Weight (g)	% Weight
Small mammals	1	1.96	55.4	0.08
Glaucomys volans	1	1.96	55.4	0.08
Medium mammals	5	9.80	2925.0	4.02
Sciurus niger	3	5.88	2031.0	2.79
Sciurus carolinensis	2	3.92	894.0	1.23
Rabbits (*Sylvilagus* sp.)	25	49.02	42500.0	58.41
Large mammals	16	31.37	26428.5	36.32
Ondatra zibethicus	7	13.73	8228.5	11.31
Odocoileus virginianus	5	9.80	10125.0	13.92
Myocastor coypus	2	3.92	4050.0	5.57
Didelphis virginiana	1	1.96	2000.0	2.75
Ovis aries	1	1.96	2025.0	2.78
Small birds	3	5.88	190.9	0.26
Eastern Meadowlark	1	1.96	104.0	0.14
Red-winged Blackbird	1	1.96	50.0	0.07
Unident. Passerine	1	1.96	36.9	0.05
Large birds	1	1.96	658.3	0.90
Shoveler	1	1.96	658.3	0.90

Table 2. Prey recovered from stomachs of female bobcats from eastern Arkansas, 1978-79 through 1980-81.

Prey	Freq. of Occurrence	% Occurrence	Estimated Weight (g)	% Weight
Small mammals	6	13.95	553.8	1.13
Sigmodon hispidus	4	9.30	401.2	0.82
Peromyscus spp.	1	2.33	23.1	0.05
Mustela frenata	1	2.33	129.5	0.26
Medium mammals	4	9.30	2708.0	5.53
Sciurus niger	4	9.30	2708.0	5.53
Rabbits (*Sylvilagus* sp.)	21	48.84	35700.0	72.95
Large mammals	3	6.98	6075.0	12.40
Odocoileus virginianus	3	6.98	6075.0	12.40
Small birds	5	11.63	423.4	0.87
Sparrow	1	2.33	24.6	0.05
Bobwhite Quail	1	2.33	209.4	0.43
Unident. Passerine	2	4.65	36.9	0.08
Common Grackle	1	2.33	152.5	0.31
Large birds	4	9.30	3477.7	7.11
Wood Duck	2	4.65	1353.0	2.76
Pintail	1	2.33	947.0	1.93
Mallard	1	2.33	1178.0	2.41

Table 3. Prey recovered from stomachs of bobcat kittens from eastern Arkansas, 1978-79 through 1980-81.

Prey	Freq. of Occurrence	% Occurrence	Estimated Weight (g)	% Weight
Small mammals	22	33.85	1643.3	5.05
Sigmodon hispidus	10	15.38	1003.0	3.08
Oryzomys palustris	5	7.69	252.5	0.78
Peromyscus spp.	2	3.08	46.2	0.14
Microtus pinetorum	2	3.08	51.2	0.16
Neotoma floridana	1	1.54	264.8	0.81
Reithrodontomys sp.	1	1.54	11.2	0.03
Mus musculus	1	1.54	14.4	0.04
Medium mammals	2	3.08	1124.0	3.45
Sciurus niger	1	1.54	677.0	2.08
Sciurus carolinensis	1	1.54	447.0	1.37
Rabbits (*Sylvilagus* sp.)	24	36.92	24300.0	74.64
Large mammals	3	4.62	3037.5	9.33
Procyon lotor	1	1.54	1012.5	3.11
Didelphis virginiana	1	1.54	1012.5	3.11
Ondatra zibethicus	1	1.54	1012.5	3.11
Small birds	10	15.38	646.9	1.99
Sparrow	3	4.62	73.8	0.23
Unident. Passerine	2	3.08	73.8	0.23
Wood Thrush	1	1.54	50.6	0.16
American Kestrel	1	1.54	112.6	0.35
Domestic Pigeon	1	1.54	250.0	0.76
Brown Thrasher	1	1.54	66.3	0.20
Carolina Wren	1	1.54	19.8	0.06
Large birds	4	6.15	1803.1	5.54
Mallard*	3	4.62	1178.1	3.62
Barred Owl	1	1.54	625.0	1.92

* three apparent litter-mates partitioned one Mallard drake, therefore weight was treated as one duck

Adult male bobcats were represented by 49 samples, of which 41 contained remains. The mean number of items recovered per stomach was 1.2 (range 1-2). One prey item occurred in 33 stomachs and 2 were found in 8 stomachs. Stomachs at least half full occurred in 52.0% of the specimens.

Food selection by adult males (Table 1) indicated rabbits to be the primary prey by occurrence and weight. Large mammals exclusive of rabbits were the second ranking food source by occurrence and weight; combined with rabbits these accounted for 80.4% of the fall and winter diet of male bobcats. Small mammals were apparently selected against by adult males.

Fall and winter diet of adult female bobcats was determined from 41 stomachs, of which 33 contained prey remains. Stomachs contained a mean of 1.3 items (range 1-3). One prey item occurred in 24 stomachs, 2 in 8, and 3 in 1. Stomachs at least half full occurred in 29.3% of the specimens.

Food selection by adult females (Table 2) indicated rabbits to dominate by occurrence and weight. Small mammals were second in importance by occurrence, followed closely by small birds, large birds and medium mammals, and large mammals. By weight, rank of importance was large mammals, large birds, medium mammals, small mammals, and small birds.

Foods of kittens was determined from 51 stomachs, of which 36 contained prey remains. Stomachs contained a mean of 1.8 items (range 1-4). One prey item occurred in 14 stomachs, 2 in 15, 3 in 4, and 4 in 3. Stomachs at least half full occurred in 45.1% of the specimens.

Food selection by kittens (Table 3) indicated rabbits to dominate by occurrence and weight. However, small mammals were very close to rabbits in importance by occurrence, although they were third by weight. Kittens more often consumed small mammals and small birds than did adults. Small mammals were most often represented by cotton rats and rice rats.

Contingency table analysis of frequencies indicated that females and kittens did not select significantly different sets of prey ($G = 7.339$, $df = 5$) but males and females ($G = 14.967$, $df = 5$) and males and kittens ($G = 20.502$, $df = 5$) differed in frequencies of size classes taken. Analysis by weight suggested similar relationships (female:kitten, $G = 4.662$, $df = 5$; male:female, $G = 18.781$, $df = 5$; male:kitten, $G = 28.310$, $df = 5$). The critical value of G at $P = 0.05$ is 11.07.

DISCUSSION

In the Delta region of eastern Arkansas, rabbits are the principal food base for the bobcat population. These results are consistent with some other studies (Progulske, 1955; Korschgen, 1957; Gashwiler *et al.*, 1960; Bailey, 1972; Hall, 1973; Fritts and Sealander, 1978; Storey *et al.*, 1982), although rabbits are sometimes of secondary importance to rodents (Kight, 1962; Miller, 1980) or deer (Hamilton and Hunter, 1939; Marston, 1942, Westfall, 1956).

Importance of rabbits as bobcat prey in the Gulf Coastal Plain (52.3% occurrence) and Interior Highlands (30.0% occurrence) of Arkansas (Fritts, 1973) is complemented by results of this study (Tables 1-3). Difference in frequencies may be due to chance, or they might reflect responses to changes in prey abundance (Bailey, 1972; Beasom and Moore, 1977). Optimal foraging theory suggests that prey should be selected which provide maximal energetic gains through minimal expenditures (Pianka, 1978). Changes in prey abundance may cause suboptimal foraging similar to (but not as deleterious as) that observed in Canada lynx — snowshoe hare cycles. Due to its size and prevalence as bobcat prey, it is likely that the rabbit is near the peak of the optimal range of prey sizes for bobcats.

White-tailed deer are large prey for bobcats to subdue, although there are numerous references to deer predation in the literature (Young, 1928; Foote, 1945; Matson, 1948; Erickson, 1955; Fritts, 1973). Eight stomachs in our study contained deer remains. Deer seasons in Arkansas are coincident with trapping seasons, and it is probable that deer are often taken as carrion or that hunter-wounded animals are taken. This argument is supported by the observation that maggots were present in the meat in 1 stomach. Other research has suggested a relationship between deer hunting seasons and bobcat food use (Pollack, 1951; Progulske, 1955; Fritts, 1973).

The results of the present study and those of Fritts (1973) do not agree in some respects, probably due to the geographic coverage of the samples. Deltaic eastern Arkansas is heavily agricultural and is along the Mississippi Flyway for waterfowl. As a result, cotton rats and muskrats were more common in bobcats from eastern Arkansas, and rice rats, nutria and waterfowl are additions to the known food list. The waterfowl may have been injured by hunters prior to capture by bobcats.

Occurrence of fish was indicated by a few cycloid scales in 1 stomach. The scales could have been ingested as trap debris, therefore fish were not considered to be a real food item. Yoakum (1964, 1965) indicated that bobcats can catch fish but they are seldom eaten.

Clearly, mammalian prey were the most important energy source for bobcats as evidenced by occurrence (82.0% of total foods) and weight (94.5% of total foods). The most important size class was the large mammal category (rabbits included). However, relative importance of taxa or size classes differed among males, females, and kittens.

Adult male bobcats relied more heavily on large mammal and rabbit groups (80.4% combined occurrence, 94.7% combined weight) than did females (55.8%, 85.4%) or kittens (41.5%, 83.9%). Male bobcats are larger than females, which may help them subdue larger or more difficult prey (only males consumed nutria and muskrat). The occurrence of only 1 or 2 prey items in males indicates the ability to satisfy energetic requirements with single captures. Further, the male is free to hunt alone, while females are seasonally burdened with kittens, and this may decrease the number of opportunities for females to successfully hunt larger or more wary prey.

Lack of use of small mammals by adult males could be due to availability of larger prey, diminishing any requirement of small mammals as a buffer food source. It is unlikely that sex-related differences in the diet occur to relieve intraspecific competition for food sources for two reasons. Firstly, the occurrence of rabbits between sexes is nearly identical. If indirect (exploitation) competition occurs between sexes and availability of primary prey items is limited, we expect little overlap (dominant prey will differ between competitors). Secondly, the bobcat is generally solitary as an adult. Same-sex home ranges show little overlap and, except during the breeding season, adult females and males are not in contact (Bailey, 1972; Guenther, 1980; Hamilton, 1982). Therefore areas of range overlap are partitioned temporally. Direct (interference) competition for a local food resource should not occur due to behavioral segregation.

Females used small mammals and small birds more often than males. Due to the size of these organisms, the relative importance of rabbits to females (by weight) was inflated compared to that of males. With respect to energetic needs, this may mean that rabbits are more important to females because females get most of their energy from that food source. Occurrence of smaller prey may also be a function of teaching foraging strategy to the young. Kittens are small and inept in predatory tactics, so mothers may use smaller, more easily caught prey to teach hunting and killing techniques. Potential losses of energy the female might otherwise gain could be invested in reproductive success by insuring survival of young. The observed low percentage of females with fuller stomachs could be due to partitioning captured prey with kittens. If this is true, the importance of rabbits in female diets is overemphasized. The partial loss of rabbit meals could also explain the need for females to consume smaller prey items, and therefore the difference between foods consumed by males versus females.

The Sorenson similarity coefficient indicated the diet of kittens to be more similar to that of females (40.0%) than to that of males (28.6%). Bobcat kittens consumed almost as many small mammals as they did rabbits, and the range and mean number of prey items in kitten stomachs further indicated the importance of small mammals. In contrast, Fritts (1973) found few rats and mice in the diets of kittens. He concluded that, because rabbits are the principal food brought to kittens by the parent, kittens concentrate on that food resource early in life. The importance (by weight) of rabbits to kittens is similar to that calculated for females. It seems plausible to assume that rabbits are of paramount importance in providing nutritional and energetic requirements to kittens for growth and development, and that kitten survival may depend on the availability of rabbits (Bailey, 1972). Stomachs were full more often in kittens than in females because smaller items fill smaller stomachs.

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PHOTOSYNTHETIC COMPETENCE OF AN ENDANGERED SHRUB, *LINDERA MELISSIFOLIA*

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ABSTRACT

Net photosynthesis and water relations were investigated *in situ* for a population of *Lindera melissifolia* in northeast Arkansas. Photosynthetic light use efficiency was found to be characteristic of a shade plant. Response of photosynthesis to temperature and CO_2 was insensitive over ranges found during the growing season. High water use efficiency was demonstrated, but under typical conditions of low light this was marginally beneficial. In comparison with competing understory plants, the species proved to be photosynthetically competent. The data are evaluated in terms of the survival potential of the species.

INTRODUCTION

Lindera melissifolia (pondberry) is an understory species of seasonally flooded bottomland hardwood forest in the southeastern United States (Klomps, 1980). It is listed as endangered by both the US Fish and Wildlife Service and the Arkansas Department of Natural Heritage. In Arkansas the habitat is exclusively the bottoms and edges of small shallow seasonal ponds in old dune fields in the northeastern part of the state. Dunes were formed from glacial outwash, and have eroded to land of low relief which is in row crops, except for depressed features such as the ponds (Saucier, 1978). Ponds fill during winter rains, usually to depths of 50 cm or less, and tend to retain water until after expansion of forest leaves. Water depth over pondberries has not been observed to exceed 40 cm in Arkansas. Pond size ranges up to several hectares, but pondberry typically exists in stands no more than 50 m across. Populations are well isolated from each other, either by cropland or by ponds having no pondberries (Wright, 1989a).

There is no indication that *Lindera melissifolia* has recently spread to new sites in Arkansas. It is therefore of prime concern that it survive in sites it now occupies, if it is to remain extant. The species reproduces by vigorous sprouting from underground rhizomes, and from seed (Wright, 1989b). Seed production has been low and erratic in 1986 through 1989, and very few seedlings have been found. Existence of some single-sex stands suggests that seed reproduction has been ineffective in this dioecious species, and that present stands represent the vegetative descendents of relatively few ancestors (Wright, 1989a).

In most locations pondberry makes closed shrub canopies with little competition from other shrubs and vines, but there are several potential competitors including *Brunnichia ovata, Smilax glauca, Sassafras albidum* and *Callicarpa americana*. This study evaluated the photosynthetic competence of pondberry during periods of spring flooding, summer drought, and low light intensity common to its habitat, including some comparisons with competing species.

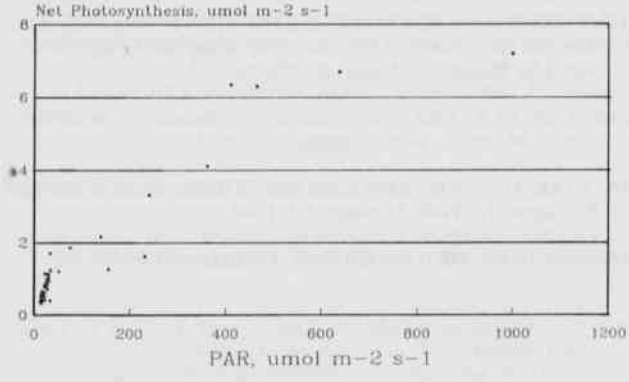
METHODS

A population in Woodruff County, AR was visited 6 times between first leaf expansion (May 12) and shortly before the onset of leaf senescence (Sept. 29). One visit was also made to a site near Swifton in Jackson County on July 14. Net photosynthesis and stomatal conductance were determined on randomly selected leaves during the course of the day, using a closed system LI-6200 Portable Photosynthesis System (LI-COR, Inc., Lincoln, NE). A 1 1 LI-COR chamber was suported by tripod so that the leaf could be enclosed in its natural orientation. UP to 5 readings were obtained from a single leaf, with the chamber open for a minimum of 60 s between readings. CO_2 span was 1 or 2 ppm for shaded leaves, and up to 5 ppm for leaves in full light. Leaf temperature was measured by a thermocouple in contact with the abaxial surface, and rose less than 1 C during runs. For each of approximately 600 rate measurements during the season, the system recorded photosynthetically active radiation (PAR), CO_2, leaf temperature and other critical variables.

Shoot water potential (WP) was determined at the start and end of each day's field work, using a PMS pressure bomb (PMS Instruments, Corvallis, OR). Leaf WP and osmotic potential were determined at the end of each day's field work, using screen cage thermocouple psychrometers (J.R.D. Merrill Specialty Equipment, Logan, UT) according to the method of Walker and Oosterhuis (1982).

RESULTS

Light intensity. Light reaching the pondberry leaves was typically at 1 to 2% of full sun PAR, or 15 to 30 umol m^{-2} s^{-1}. Leaves reached about 20% of their light-saturated rate of net photosynthesis at these low intensities (Fig. 1). Net photosynthesis was attained at PAR as low as 5 umol m^{-2} s^{-1}, and was highly correlated with light intensity ($r^2 = .86$, $P < .00001$).



PHOTOSYNTHESIS vs. LIGHT
Figure 1. Net photosynthesis of *Lindera melissifolia* related to light intensity.

In sun flecks light intensity exceeded 1000 umol m^{-2} s^{-1}. Comparable intensities wer reached in large canopy gaps. Where pondberries occurred in these large gaps they produced a thicker sun leaf capable of over twice the rate of net photosynthesis as shade leaves in sun flecks of comparable intensity. At light levels greater than 970 umol m^{-2} s^{-1}, ambiant CO_2 of 350 ± 10 ppm and leaf temperature of 37 ± 1 C, net

photosynthesis of sun leaves was 9.9 umol m^{-2} s^{-1}, while net photosynthesis of shade leaves was 4.4 umol m^{-2} s^{-1} (t-test $P<0.0001$).

Temperature. Daytime leaf temperatures under the closed tree canopy were generally between 25 and 35 C during the growing season. In low light characteristic of this habitat (20-35 umol m^{-2} s^{-1}) net photosynthesis was not correlated with temperature over the range 24.15 - 33.4 C ($r^2=.09$, $P>.05$). In the large canopy gap containing plants with sun leaves, leaf temperatures on July 14 ranged from 34.28 to 41.29 C. Net photosynthesis of these well-lit leaves was also not correlated with temperature ($r^2=.004$, $P>.9$).

Carbon dioxide. Ambient CO_2 levels ranged from around 400ppm early in the day to 350 ppm from late morning on through the end of the light period. During the morning transition net photosynthesis was weakly correlated with CO_2 (366-408ppm, leaf temp 28 $\pm$2 C, PAR 15-20 umol m^{-2} s^{-1}, $r^2=.25$, $P<.05$). At slightly higher light intensities, PAR 30-36, there was no significant correlation between net photosynthesis and CO_2 over a range of 351-398ppm.

Water relations. Leaf and shoot WP ranged between -0.5 MPa and -1.0 MPa throughout the season whenever soil moisture was high (above $-.01$ MPa in the root zone). On 18 August after a period with little rain, leaf and shoot WP were between -1.0 and -2.0 MPa, with soil WP from -0.1 MPa to -1.0 MPa. Analysis of Variance (ANOVA) revealed no significant differences in plant moisture stress among dates, beginning and end of days, or method of determination ($F=0.67$, $P>.8$).

Under midday levels of CO_2 (350 $\pm$ 15 ppm) and low light (PAR 15-30 umol m^{-2} s^{-1}), net photosynthesis was correlated with stomatal conductivity ($r^2=.2$, $P<0.01$) but not with leaf WP ($r^2=.04$, $P>0.10$ for PMS bomb, $r^2=.01$, $P>0.5$ for psychrometer). At PAR above 200 umol m^{-2} s^{-1} in the same CO_2 range, net photosynthesis was correlated with both stomatal conductivity ($r^2=.36$, $P<.001$) and leaf WP (PMS bomb $r^2=.74$, $P<.0001$; psychrometer $r^2=.60$, $P<.0001$).

The above water relations results were obtained on data gathered throughout the growing season. Data from one day, June 14, were used in addition to calculate water use efficiency (WUE), net photosynthesis/stomatal conductivity. Regression analysis revealed correlation of photosynthesis with stomatal conductivity ($r^2=.60$, $P<0.0001$) and with WUE ($r^2=.65$, $P<.0001$).

Competition. Net photosynthesis and stomatal conductance were determined for competing species in the shrub layer and compared with performance of pondberry under the same conditions. Environmental parameters were: temperature, 30 $\pm$ 2 C; PAR 25-30 umol m^{-2} s^{-1}; CO_2 360 $\pm$ 15 ppm. Results are shown in Table 1.

Table 1. Net photosynthesis and stomatal conductance, umol CO_2 m^{-2} s^{-1}.

	photosynthesis	conductivity
Brunnichia ovata	1.05 ns	0.21 *
Callicarpa americana	0.97 ns	0.13 ns
Lindera melissifolia	1.04	0.10
Smilax glauca	1.02 ns	0.14 ns
Sassafras albidum	0.80 ***	0.05 ***

T-test comparisons with Lindera melissifolia, ns=P>.05; *=P<.05; ***=P<.001

DISCUSSION

With rare species found in a few isolated locations scattered over a considerable range, it seems likely that distribution was once more continuous. An important question is whether loss of stands has been due to stochastic events, either natural or man-caused, or to natural selection. If survival has been due to chance, extant populations would not necessarily be well adapted to their sites, whereas forces of natural selection would tend to have weeded out poorly adapted populations. Although limited largely to one population, this study indicates that pondberry possesses several physiological adaptations appropriate to its habitat, and may therefore have been selected for the sites where it grows.

In its dune ponds under hardwood forest canopies, pondberry clearly escapes some stresses. Light levels are low, daytime leaf tempratures are moderated, and transpiration stress is thereby reduced. Net photosynthesis was competent at light levels typical of shaded conditions, and indicated that the species possess properties of shade plants (Boardman, 1977). Net photosynthesis did not respond significantly to leaf temperature over ranges found throughout the day and season. Since temperature is typically correlated with net photosynthesis (Pearcy *et al.*, 1987), it must be that other limiting factors are more critical here. Light is a likely critical factor at the low irradiances normally found in pondberry habitat.

CO_2 was weakly correlated with photosynthesis at very low (15-20 umol m^{-2} s^{-1}) light but not in slightly brighter conditions (30-36 umol m^{-2} s^{-1}) typical of the shaded habitat. Thus response to CO_2, widely demonstrated at higher light levels in many studies (Strain and Bazzaz, 1983) is apparently suppressed under these conditions of light limitation, as found by Zangerl and Bazzaz (1984) for 6 co-occurring disturbed site annuals.

A review by Strain (1985) suggested that stomatal conductance and CO_2 may cancel each other in their combined effect on net photosynthesis. As pointed out by Farquhar and Sharkey (1982), stomata impose less limitation on photosynthesis at low irradiances. Leaf water potential did not correlate with net photosynthesis under typical shaded conditions (15-30 umol m^{-2} s^{-1}), but only under high light (above 200 umol m^{-2} s^{-1}). Gauhl (1979) demonstrated a similar response of shade ecotypes of *Solanum dulcamara*.

The above findings indicate that in the benign environment where it grows, pondberry is buffered against some potential stresses. Other woody competitors may of course enjoy the same buffered conditions, and could conceivably respond more favorably to them. Of the 4 principal competitors, none showed more efficient rates of net photosynthesis, and one, *Sassafras albidum*, was less efficient. At the same time its stomatal conductivity was lower, making it potentially more drought-tolerant. Another competing species, *Brunnichia ovata*, had stomatal conductivity higher than pondberry, increasing its susceptibility to drought, but gained no advantage in net photosynthesis. I have found that under drought more severe than occurred during 1988, the competing species became deciduous more rapidly than pondberry (Wright, 1989a). Thus *Lindera melissifolia* in general displayed photosynthetic competence comparable to that of its competitors under undisturbed conditions.

Although an efficient photosynthesizer in low light, pondberry can respond to large canopy gaps with the production of sun leaves (Wright, 1989a). These had more than twice the photosynthetic capacity of shade-grown leaves, well within the fivefold potential range suggested by Bjorkman (1981). Net photosynthesis of competing woody understory species was not measured under large gap conditions, but they were observed to grow vigorously. The vines *Brunnichia ovata* and *Smilax glauca* easily overtopped pondberries. Along with vigorous growth of herbaceous old-field species in large gaps (Wright, 1989a), this suggests that pondberries could be suppressed in large canopy gaps.

Percent of total daily photosynthesis occurring in light flecks under the closed canopy was not evaluated. While this may be appreciable (Chazdon, 1986), it does not appear to work to the detriment of pondberry.

While the pond sites have saturated soils into the growing season, soil water potential will drop in summer droughts. Even though 1988 was considered a dry year, precipitation was fairly timely at the study site, with soil WP observed dropping to -1 MPa on only one date. Across the range of leaf WP on June 14, when soil WP was high, pondberry demonstrated good stomatal control. Net photosynthesis was well correlated with both stomatal conductivity and WUE on this date, when irradiance ranged from 15 to 1000 umol m^{-2} s^{-1}.

Lindera melissifolia thus proves to be photosynthetically competent in a dune pond site in Arkansas. If the forest canopy were opened to

permit large light gaps this picture could change, but in undisturbed dune ponds the species appears fairly secure. Clearing for farming may be constrained by the "Swamp Buster" provisions of the 1985 Farm Act, but permitted agricultural interference with dune hydrology still has the potential for altering pond depth or duration, thus affecting growth of competing species. It is also not known whether the species, which is dioecious, is sexually dimorphic in ways that affect physiological competence. The questions of hydrology and sexual dimorphism are currently under investigation.

It appears that under the newly unified Federal methodology for identifying and delineating wetlands (Anthony V. Nida, Corps of Engineers, pers. comm.), all the ponds and possibly their surrounding dunes will quality for protection. This will enhance survival of pondberry in Arkansas.

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GENERAL NOTES

IMAGE ENHANCEMENT OF FADED HISTORIC DOCUMENTS

The need to preserve historic documents is generally recognized and few would deny that these documents become more valuable with the passage of time. Unfortunately, as time passes, the document becomes faded and/or tattered making it less and less legible. Methods are available to increase the life of the original, but these often inhibit access. Facsimiles are often used to circumvent this problem. But many facsimiles procedures have limitations; for example, a first generation copy is better than a second generation copy and successive copies lose information. Digital (or computerized) copies overcome many of the obstacles encountered with the present methods of preservation.

"Digital computer image enhancement has proven highly useful in numerous fields. Remote sensing, astronomy, and medical diagnostics in particular have experienced quantum leaps in performance through the introduction of this technology". (Asmus, John F., "Digital Image Processing in Art Conversion", *BYTE*, March 1987, p. 151). With a digital copy, the document can be viewed as having an extremely fine grid of points. These points or dots (often called pixels) can be turned on or off in a simple "line art" copy, or they may have different intensities, or gray scales, to provide a copy of black and white photographs. Finally, they may have both intensity and color to provide a full color copy. These computer generated copies have several advantages: 1) they do not exhibit degradation over time other than the risk (which can be minimized) of losing the copy or corrupting the data; 2) a tenth generation copy is as good as a first generation copy; 3) they can be easily exchanged by using electronic media or electronic transmission; and 4) most importantly, they lend themselves to computer indexing and retrieval so they may be retrieved in milliseconds and viewed on video screens.

Traditional methods of image enhancement involve "gray scale reversal, stretching of gray levels, modification of the histogram to the desired function, and so on". (Chellappa, Rama and Alexander A. Sawchuck, *Digital Image Processing and Analysis*, Vol. 1, 1985, p. 426). Several areas of enhancement have emerged. These consist of optical character recognition, satellite imaging and medical photography, to name a few. As most of these areas are unrelated, what is available today is a collection of algorithms and functions which may or may not apply to a given image.

A primary obstacle of digital copies has been the very large amount of data (and associated cost) required for a copy. Several developments have occurred which lessen this problem: 1) computers are much faster and the speed is doubling about every 2 years; 2) the cost of storing digital data is dropping by half every 2 years. The development of data compression algorithms also significantly reduce the data storage requirements. Taken together, digital archives are a viable alternative today, and a near certainty for the future.

This paper explores the unique problems associated with digitizing old documents that contain handwritten script. Additionally, a method is suggested for accurately capturing the image data.

This project consists of an interdisciplinary approach to providing an alternate method of document preservation. Several branches of the humanities, coordinated with computer science and engineering at the University of Arkansas in Fayetteville will be involved.

The proposed project task force is centered around a newly formed History Technology Laboratory at the University of Arkansas. This group consists of a board which contains representation from engineering and the humanities. The humanities reprsentatives make up a majority of the group. History, library science and literature represent some disciplines within the humanities in this group.

Many books and documents address the topic of image processing. Most of the existing image processing systems are expensive and difficult to access and use; however, many of the techniques and algorithms used in existing systems and described in current books can be utilized in this project.

The National Archives and the Library of Congress are developing a similar type of imaging system. Recent contacts with personnel at the Library of Congress indicate that there are some complexities in their system. These larger systems typically are few in number and complicated to use. One of the goals of this project will be to produce a prototype which will be cost effective and easy to use. The prototype should have the capability of recovering difficult to read text and producing a facsimile which would be representative of the original document.

This work was performed on a 386 based machine with a high resoluton (1,024 X 768) monitor. The output is from a 300 DPI HP Laserjet. Higher output densities are available but are not yet implemented. Alternate storage devices (tape, optical disk, etc.) are being evaluated and efforts are underway to find or create an image database front end.

A typical old document contains nothing other than freehand script. Typically, the quality of the paper and the legibility of the text vary throughout the entire length and width of the document. Thus, some parts of the page will be clearly legible while other parts may be totally illegible. Refer to Fig. 1. "A basic tool utilized in performing subjective enhancement and image analysis is the image histogram. The histogram reveals the distribution of digitized intensity within an image....". (Green, William B., *Digital Image Processing, A Systems Approach*, 2nd ed., p. 64). Since each document has such variations as described above, difficulty often exists when applying a single algorithm to the entire histogram. Any enhancement scheme which applies to the entire document must take this into account.

Existing systems are rarely applicable in this situation. Optical character recognition, satellite and medical imaging contribute concepts and general guides to script enhancement but do not provide a total solution. Algorithms which affect the entire page can be utilized to improve the quality of a document to some degree. The algorithms utilized on the letter in Fig. 1 were (in order): 1) adjusted brightness, 2) adjusted contrast, 3) performed linear equalization and 4) sharpened the image. The algorithms produced Fig. 2. Notice that there are 2 horizontal areas splitting the document into thirds. These are folds in the paper. To make matters worse, at some time in the past scotch tape was applied to approximately two-thirds of these areas starting at the left edge. Figure 3 displays a blow up of part of the lower band. (The vertical and horizontal measurements were altered automatically by the software in an attempt to fit the picture on a single page.) Figures 4 and 5 represents a best attempt to clarify the words underneath the scotch tape. The letters barely become readable in Fig. 6.

The intent is to create a proximity algorithm to locate and enhance line segments. Figure 7 shows the desired end result. Lines will typically have characteristics which distinguish them from other marks. Lines will normally be of a consistent gray level in a continuous fashion and further will not be "very wide". These features will allow the algorithm to discern the difference between the background and the line.

The first 75 (¼ inches at 300 DPI) rows of pixels are read into the computer memory from the image file. The entire document cannot be read at once due to hardware and software requirements. The algorithm must then perform 2 functions. The first executes the necessary steps required to locate a line segment. The second "traces" the line segment and records the locations of those pixels which are recognized as part of a line into a table. The remaining pixels are then turned to white. The information is written back out to disk after performing these 2 steps. The script may then be enhanced through the use of readily available software by adjusting brightness and contrast levels.

Script detection on older manuscripts has been discussed with relationship to existing enhancement systems. In older manuscripts, existing algorithms proved inadequate. The need for new algorithms led to the formation of an History/Technology Laboratory. The purpose of the laboratory in regards to this project was to establish algorithms which are specific to script detection. Investigation of present technology led to the development of a proximity algorithm which locates and "traces" a line segment. This paper also included an example of an enhanced document.

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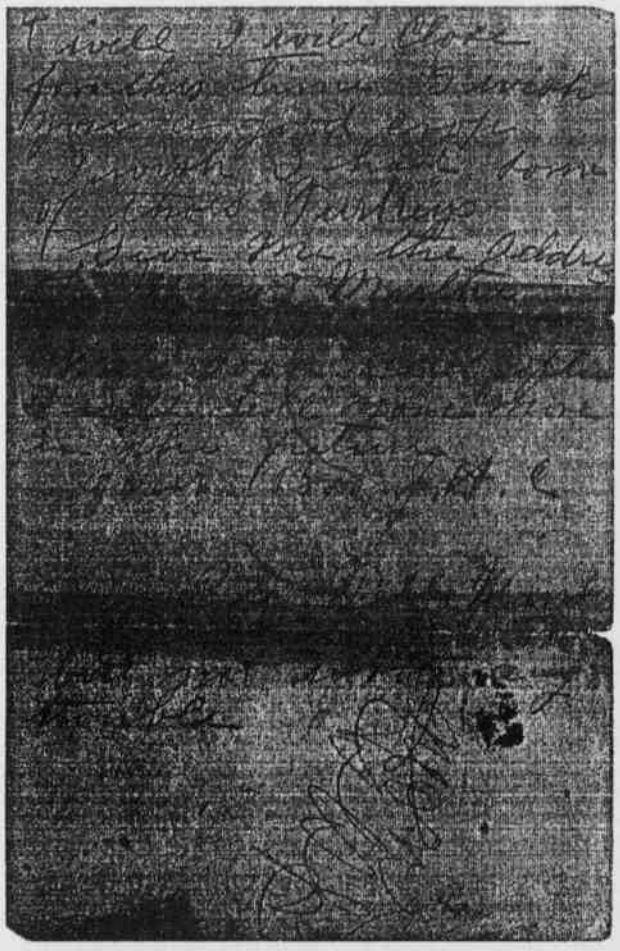

Figure 1. Original document produced in 1900

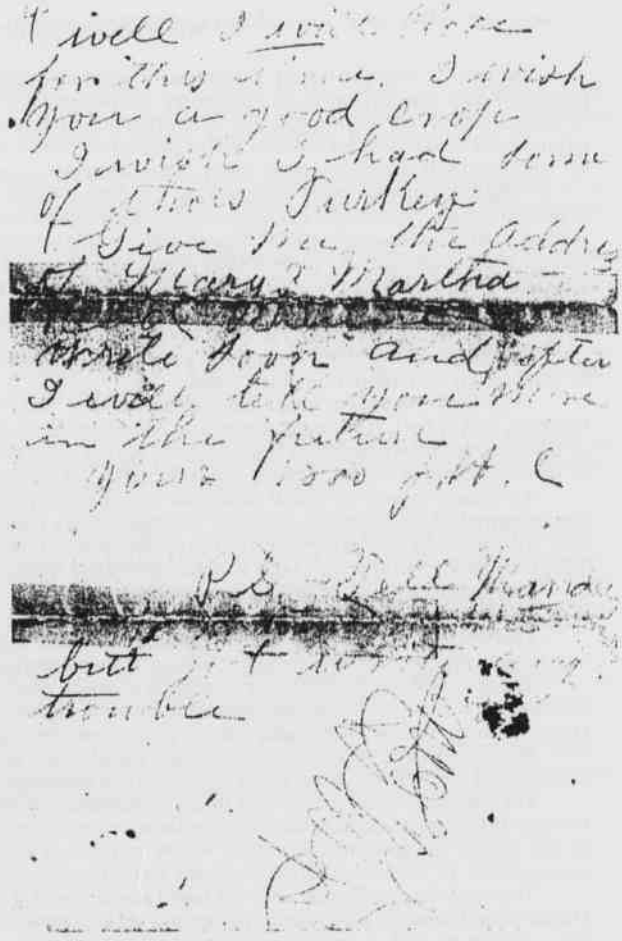

Figure 2. Original document after adjusting brightness and contrast, applying linear equalization and sharpening the image.

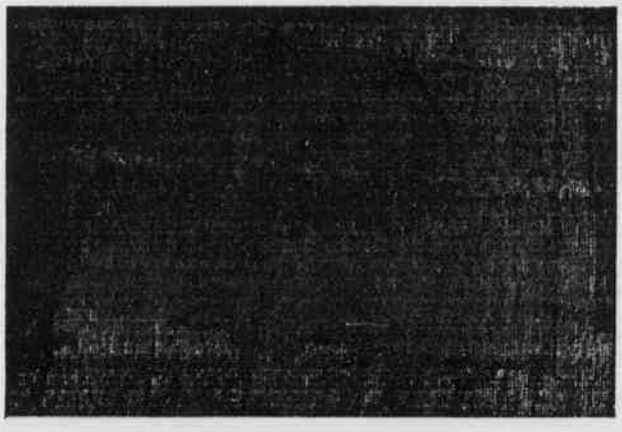

Figure 3. Small section of original document

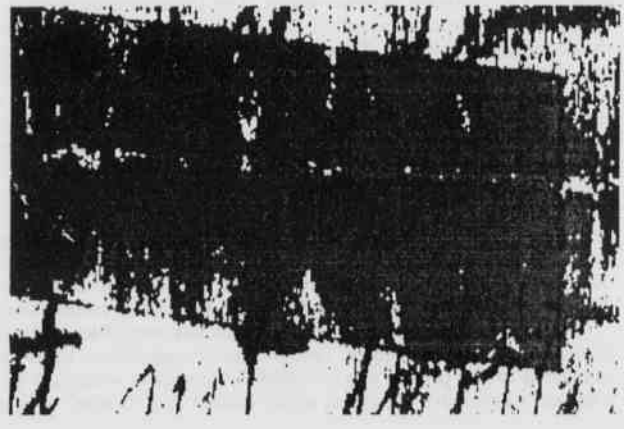

Figure 4. Figure 3 after applying threshold filter

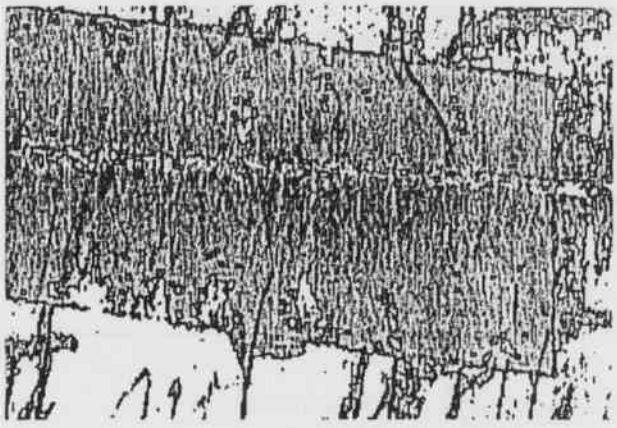

Figure 5. Figure 4 after applying equalization and sharpness

Figure 6. Figure 5 after applying contrast and brightness

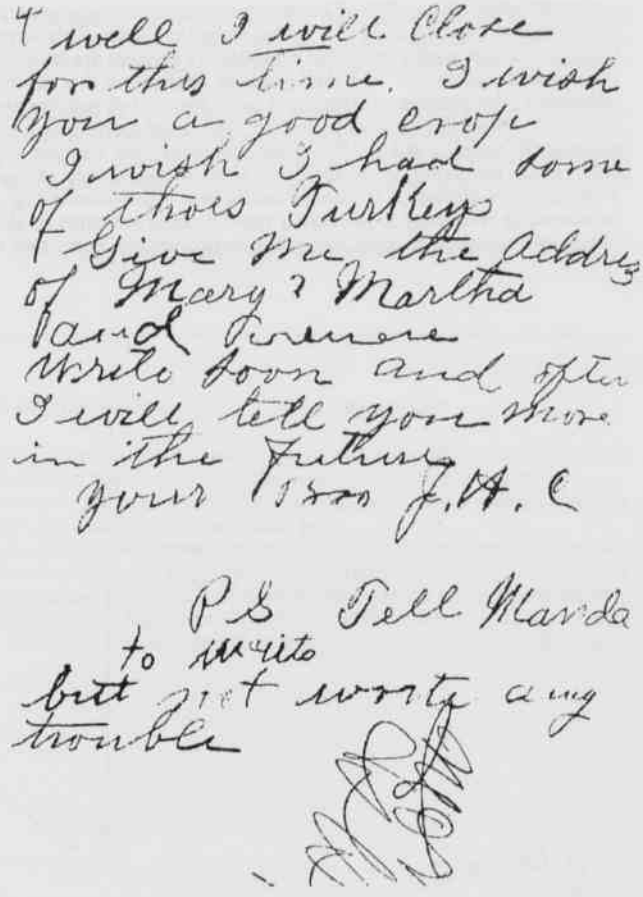

Figure 7. Desired end result after applying proximity algorithm

THE IMPACT OF MICROPROCESSOR PROTECTED MODE PROGRAMMING ON UNDERGRADUATE EDUCATION IN ENGINEERING TECHNOLOGY

The purpose of this paper is to examine some of the rapid changes that have recently occurred (and are continuing to occur) in microcomputers and the impact of these changes on both faculty and students in engineering, technology, and related fields — such as physics, biology, mathematics, and chemistry.

A microcomputer is any computer that uses a microprocessor for its central-processing-unit (CPU). In fact, a "microprocessor" can be described or defined as a CPU on one integrated circuit or "chip." Because of their small size and low cost, microprocessors, which were first developed in 1971, have revolutionized the computer industry. Before the advent of microprocessors, all computers were generally classified as main-frame or mini computers. Since main-frame and mini computers are usually very large and expensive, their resources are almost always shared by several users. By using microprocessors for the central processing unit, manufacturers were able to develop much smaller and less expensive computers. By 1981, improvements in capabilities of microprocessors led to the development and introduction of the now famous IBM Personal Computer (PC). The PC was different from existing mini computers and main-frame computers because it was intended for use by one person (single-user), and the software operating systems developed for the PC's (PC-DOS and MS-DOS) further limited the PC's to one user application program at a time (single-tasking). Performance improvements in existing characteristics such as operating frequency, address and data bus size, and chip integration are considered *evolutionary* changes in microcomputers. For example, the operating frequency of microcomputers has increased from one megahertz (MHz) to 33 MHz in the last 10 years. While this is a significant increase in operating frequency, 33 MHz is not even close to the current state-of-the-art in supercomputers such as the Cray computers which operate in the 300 MHz range. Of course, the Cray does not use

a microprocessor as a CPU. The data bus size in microcomputers has increased from 8 to 32 bits, and the address bus size in microcomputers has increased from 16 to 32 bits in this same time span. This increase in address bus size has increased the amount of physical memory from 64 kilobytes to four gigabytes. These evolutionary changes are currently available in microprocessors operating in what we now call the "real" mode, which means single-user and single-tasking application that use only physical, i.e., "real," addresses. Using very large scale integration (VLSI) techniques, the number of transistors per integrated circuit has also increased dramatically from less than 30 kilo transistors per chip in 1978 to over one million transistors per chip in 1989. Intel Corporation predicts that "by the year 2000, the 100 million transistor i786 [microprocessor] will appear, running at 250 MHz while occupying only 1 square inch." (Intel, AT DEADLINE, page 1, August 31, 1989). The rate at which these changes are occurring can be displayed in many ways, such as operating frequency, millions-of-instructions per second (MIPS), dhrystones, and whetstones. A display of frequency versus time is provided in Fig. 1 because the shape of this curve dramatically indicates that the rate-of-change in operating frequency is increasing rapidly. Improvements in electronics technology invariably lead to improvements in computer technology. Major evolutionary changes occur in microcomputers every two or three years.

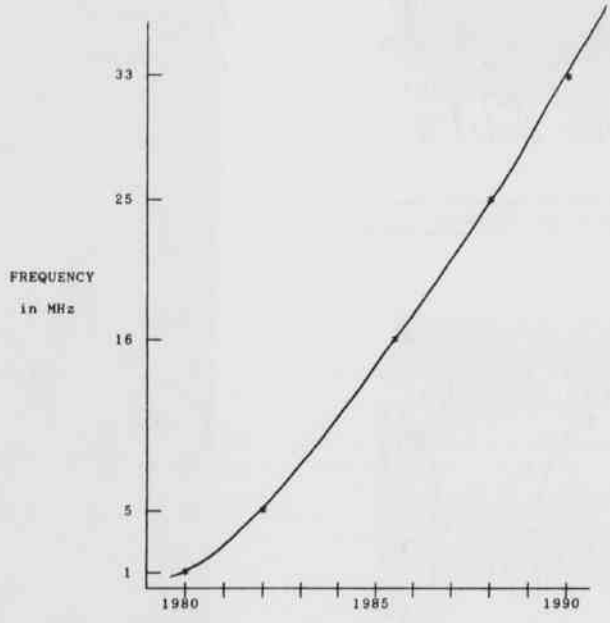

Figure 1. Improvement in operating frequency.

Any change that affects the way that a microprocessor fetches and executes instructions is considered to be *revolutionary* instead of evolutionary. Examples of revolutionary changes are pipelining, cache memory, protected mode operation, and virtual addressing mode operation. Revolutionary changes often lead to new "generations" of microprocessor. Pipelining, which requires additional hardware inside a microprocessor, speeds up operation by allowing several functions to be accomplished simultaneously. Pipelining allows one unit in a microprocessor to execute one instruction while another unit is fetching the next instruction and/or data. Cache memory, which consists of a small amount of very high speed static chips, permits the use of low cost, high density dynamic chips for the bulk of the memory with very little loss in performance. The most important recent development in microprocessors is the addition of a memory management unit (mmu) and associated system registers in the microprocessor chips. The addition of these components allows these microprocessors to operate in a real mode or a protected virtual addressing mode (also referred to as the protected mode). Intel 80286, 80386, and 80486 (microprocessors are examples of devices that can be operated in either the real mode or the protected mode. In the real mode, these microprocessors provide improved performance while maintaining compatibility with software written for earlier microprocessors which do not have an internal mmu and system registers. In the protected mode, these microprocessors provide multilevel protection for multi-tasking and task switching. The virtual addressing capability of the 80386 and 84086 provides programmers with a logical addresses into the physical *per task*. The mmu maps these logical addresses into the physical address space. PC-DOS and MS-DOS support operation in the real mode only. OS/2 and UNIX operating systems support operation in either the real mode or the protected mode.

The rapid changes that are occurring in microcomputers are affecting both faculty and students. Most faculty members are forced to learn new hardware and software concepts on their own. The integration of new computer concepts into classes has been very uneven because there are very few specific requirements to use computers in the learning process.

Actually, there are a variety of courses available for faculty development. The American Society for Engineering Educators (ASEE) has a very popular summer program that pays the tuition for faculty to attend intensive two week courses at selected universities in the United States. These courses are taught by regular faculty, and they cover all of the material that is normally covered in a semester. I recently completed one of these ASEE courses in VLSI design at the Massachusetts Institute of Technology (MIT). Many companies allow university faculty to attend their training classes free. Most of the material used in the microprocessor classes that I teach comes from short courses taken at Intel Training Centers.

Curriculum development is also affected by the rapid changes in microcomputers. One of the faculty members in Electronic Engineering Technology at Memphis State University recently developed and started teaching a new course in electronic computer aided design (CAD) that provides students with the computer expertise needed to design complete electronic circuits, test these circuits using simulation, do a parts layout, and design a printed circuit board. Equipment that can use the output from this CAD software to make printed circuit boards using numerical controlled machines is currently being investigated.

The rapid changes in microcomputer hardware and software make maintaining state of the equipment very expensive. The use of new or revised software often requires upgrading or even replacing existing operational microcomputers. Replacing operational microcomputers is often difficult to explain and justify.

General Notes

What about the future? We must shift our emphasis from courses that use computers as tools to courses that use computers as an integral part of the learning process. Cognitive science and neuroscience are being used to create new models that can be used to analyze the behavior of students in problem solving. We need to find ways to combine the computing power available in the new microcomputers with this model to improve our educational techniques.

The latest revolution in microprocessors has been used to create computers that look like a PC but have the multi-tasking multi-user capability of mini computers and main frame computers. To utilize fully these capabilities, advanced operating systems such as OS/2 or UNIX must be used. Evolutionary and revolutionary changes in computers are occurring so rapidly that many educators and educational institutions have been unable to utilize fully the phenomenal computing power that is available today. As educators, we need to find ways to use these new computers as an integral part of the learning process.

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CHARACTERIZATION OF RADIOACTIVITY IN HOT SPRINGS NATIONAL PARK, ARKANSAS

The objective of this study was to determine the types and measure the levels of radioactive emissions found within the Hot Springs National Park boundaries. The study should help determine if the emissions pose a significant health hazard to the public or to park workers.

The thermal springs of the Hot Springs National Park at Hot Springs, Arkansas, are radioactive. These springs have been a natural resource of international renown for many years. Many tourists are attracted to the spa city and visit the park each year.

The National Park is nestled in the eastern portion of the Ouachita Mountains in west Central Arkansas. The springs emerge in a compact belt about one-fourth mile long and a few hundred feet wide, along the southwestern slope of Hot Springs Mountain. Excavation and covering of springs, to increase and concentrate flows, have reduced the number of spring openings from 72 to less than 40. Each spring opening is completely encased in metal and concrete and capped with a gas-tight metal hatch. A gravity collecting system (Figure 1) channels the flow of the springs to a central reservoir (Hanor, 1980), from which the water is redistributed to individual bathhouses and to public drinking fountains (Bedinger, *et al.*, 1979).

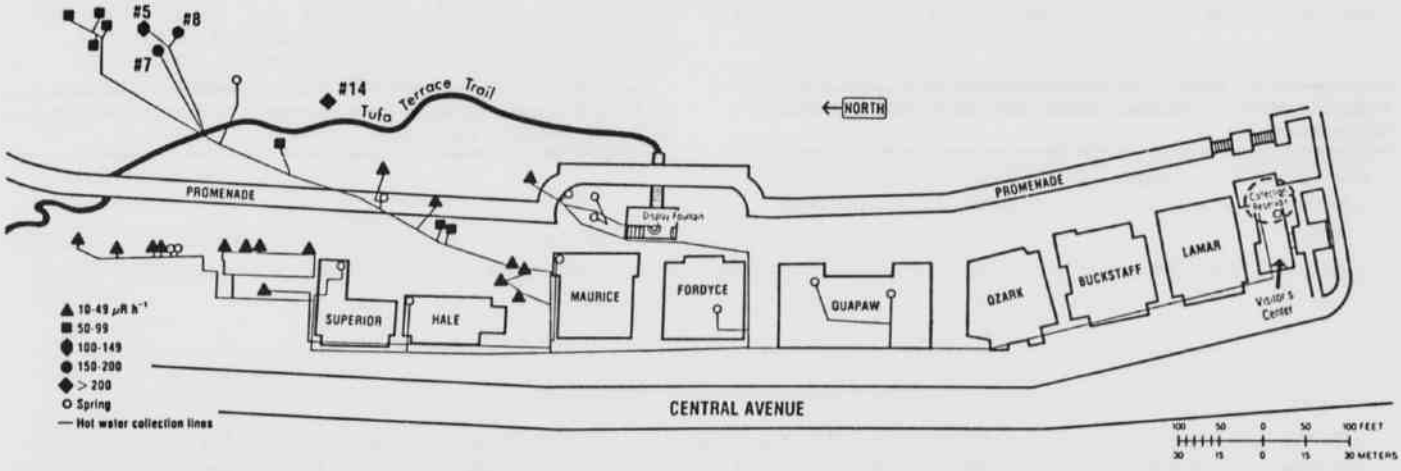

Figure 1. Distribution of the springs and bathhouses. Measured exposure rates of springs are depicted by geometric symbols. Units are μRh^{-1}.

The combined flow of the hot springs is currently about 670,000 gallons per day. The flow of the springs is highest in the winter and spring and is lowest in the summer and fall. While the temperature of individual springs may vary, the temperature of the combined hot springs waters is about 62 °C.

The radioactivity of the hot springs waters is due mostly to dissolved radon and radon daughters with a small contribution from radium. USEPA reported a radium concentration in the waters of 2.1 ± 0.22 pCi L^{-1} (Bedinger, *et al.*, 1979). The radon concentration of 25 hot springs ranged from 140 to 30,500 pCi L^{-1} with a model value of 820 pCi L^{-1} (Kuroda, 1953).

Radon concentrations were measured using passive alpha track monitors (ATM) (Ronca-Batista and Magno, 1988) and, in some cases, activated charcoal (AC) canisters (Gray and Windham, 1987). A pressurized ion chamber (PIC) and environmental thermoluminescent dosimeters (TLD) were used to make differential and integral exposure measurements of radon daughters. Gamma ray identities were confirmed using a portable multichannel analyzer (MCA) with a sodium iodide probe. A proportional probe and counter were used for charged particle detection. Several consecutive PIC readings were taken and averaged for each measurement. ATMs and TLDs were left in place for at least 90 days. AC canisters were placed for 48 hour periods. Some measurements have been made year round over the past 2 years.

External gamma fields were measured by placing the PIC in direct contact with spring covers or as close as possible to the region of interest. A map of the area and the exposure levels are shown in Fig. 1. The springs are numbered according to the Park Service's system. The largest exposure rates were observed from springs located at higher elevations. Rates decrease considerably at lower levels. This is probably due to the migration of radon gas back up the gravity collection system to higher elevations.

A highly localized area of relatively intense gamma radiation was found at an abandoned spring site on the upper slopes. This was the former site of the Ral Spring (#14). The spring has been filled in with gravel and soil. The reason for the unusually high exposure rate at this particular spot is presently unknown.

A portable shelter was erected at the Ral spring site to protect monitors and instruments from rain. The low levels of radon and abundance of gammas (Table 1 and 2) indicate that the activity is below ground. This area is an external, not internal hazard. The 2 tables illustrate the reasonably good agreement between different monitoring methods for radon and for daughters.

An ATM and a TLD were placed side by side in each bathhouse basement for 110 days. Short term PIC readings were taken at the same location and averaged. The results are displayed in Table 3.

All bathhouses except one, the Buckstaff, are closed. Elevated radiation readings were found in those basements with flowing springs that leaked or seeped onto the basement floor. Radon levels were surprisingly low, since the bathhouses were sealed and had little or no ventilation.

Family dwellings and other buildings within the reservation were assayed in the same manner as before. Results are tabulated in Table 4. The Park Service ranger station basement was found to be slightly elevated in radon levels.

Table 1. Outdoor Measurements of Radon Over Inactive Spring (Ral)

Measurement Number	2-Day Charcoal Adsorption	90-Day Alpha Track
	$pCi\ L^{-1}$	
1.	3.4	2.5
2.	3.4	2.0
Average	3.4	2.25

Table 2. Outdoor Measurements of Gamma Rays Over Inactive Spring (Ral)

Measurement Number	PIC[a] $\mu R\ h^{-1}$	TLD[b] mrem
1.	326	888
2.	316	925
Average	321[c]	907

[a] Instantaneous rates measured over a few minutes

[b] Integrated over 110 days

[c] 321 $\mu R\ h^{-1}$ = 847 mR over 110 days

Table 3. Results Obtained from Spa Bath House Basement Measurements

Bath house	Radon[b] $pCi\ L^{-1}$	TLD[c] mrad	PIC[d] $\mu R\ h^{-1}$
Lamar	3.1	30	9.6
Buckstaff	3.8	40	6.8
Ozark	8.3	30	12.0
Quapaw[a]	8.0	87	60.0
Fordyce[a]	1.3	49	13.2
Maurice[a]	2.7	30	6.7
Hale[a]	43.7	49	20.3
Superior[a]	9.9	52	12.5

[a] Active spring in basement.

[b] 110 day alpha track monitors.

[c] 110 day thermoluminescent gamma monitors. These include normal background of about 30 mrads.

[d] Averaged instantaneous exposure rates measured over a few minutes.

Table 4. Results Obtained from Basements of Family Dwellings and Buildings Within Reservation

Location	Radon[a] $pCi\ L^{-1}$	TLD[a,b] mrad	PIC[c] $\mu R\ h^{-1}$
Ranger Station	5.1	42	10.3
Dwelling 1	2.6	47	9.8
Dwelling 2	2.5	46	10.5
Dwelling 3	2.0	42	10.2
Health Club	1.5	37	7.4
Visitor's Center	1.5	55	10.0
Maintenance Shop	0.8	36	7.9

[a] Integrated over 110 days

[b] This includes an average TLD background of 30 mrads

[c] Instantaneous rates measured over a few minutes

The effect of exposing thermal spring enclosures to the ambient atmosphere is demonstrated in Table 5. Initially the exposure rates of 3 springs were measured with the PIC in contact with the spring covers. Two of the spring covers were then removed, exposing the spring opening to the outside atmosphere. After 1 hour, the covers were replaced and exposure rates re-measured. Two days later the readings were back to normal. The results indicate that once disturbed, equilibria between radon gas and radon daughter plateout under the spring hatch lid is quickly restored.

The exposure rates measured at various times during a year are shown in Table 6. Radioactivity appears to decrease somewhat during the colder months. More likely, this reflects the seasonal decrease in spring flow rates. Repeat measurements are very consistent.

Salient observations from this study include the following:

—Radon levels in dwellings and other park buildings are below any current action level.

—Bathhouse basements have some potential for becoming hazardous but this can probably be remedied with ventilation and sealing of cracks.

—The highest external exposures exist over and immediately adjacent to thermal spring openings.

General Notes

—Essentially all spa areas were found to be well within acceptable radiation exposure limits.
—Radon and daughters comprise essentially all of the radioactivity present in the park.
—Dried up springs no longer emit gamma rays. The presence of water is evidently necessary for gamma emissions to exist.

Table 5. PIC Reading Over Hatch Covers - Before and After Opening

Spring Number	Before Hatch Removal	$\mu R\ h^{-1}$ After Hatch[a] Replacement	48 hours Later
5.	133	65	136
7.	189	[b]	190
8.	151	55	161

[a] Spring was opened to ambient atmosphere for one hour before replacing hatch cover.

[b] Hatch not removed.

Table 6. PIC Measurements at Spring Hatch Covers Across Time

Date	Spring Number #5	#7 $\mu R\ h^{-1}$	#8
July 1987	142	185	-
Oct 1987	116	163	-
Nov 1987	119	171	-
Feb 1988	119	-	158
Apr 1988	122	-	164
May 1988	133	189	151
May 1988	136	190	161

- No reading taken

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STATUS OF THE ACCELERATOR PROJECT AT U.C.A.

A 2.5 MV Van de Graaff accelerator is being installed in a new facility at the University of Central Arkansas. The accelerator and some ancillary hardware was donated to the school approximately 10 years ago, while the area in the building became available almost 4 years ago.

The accelerator itself is one of many variants in a series produced by High Voltage Engineering Corporation. Built in the late 1950's, it has passed through several institutional hands in the interim, but has acquired relatively little actual running time. It was originally intended for use with a negative terminal potential to accelerate electrons, as part of an industrial X-ray system. Our use for the machine has required a conversion to positive terminal operation to produce positive ion beams. A more detailed discussion of these modifications and the installation to date appears below.

The laboratory housing the accelerator was designed expressly for that purpose as part of an addition to the science building completed in 1986. It consists of 4 rooms on the main (upper) floor of the building and one large room below them. Figure 1 shows a plan view of the upper floor area and Fig. 2 shows the lower room.

In Fig. 1 we see 2 primary rooms, the control room and the accelerator vault. The control room is outside the curved shield wall of the vault; it houses the control console for the machine as well as providing space for data acquisition equipment. The 2 smaller rooms to the left of the vault will provide office and research area to faculty and students using the machine.

The accelerator vault is 7.9 m in diameter and is enclosed by a high density concrete radiation shield wall; this room and the entire lower room, equally shielded, constitute the high radiation area of the laboratory. This area is protected against entry when radiation may be produced by a system of interlocks on all entrances.

The accelerator is mounted vertically at the vault center so that the beam will immediately exit into the target room below. The machine's baseplate (A) is shown in Fig. 1, and is approximately 1.2 m square. The accelerator pressure tank stands roughly 2.4 m high and is removed and installed with an overhead track crane. A floor slot (B) allows crane access to the target room below. A large conduit (C) carries control cables from the machine baseplate to the console (D). Gas storage and piping equipment for the insulating tank gas will be installed in the vault.

A stairway leads down to the target room, which occupies the area below all of the upper floor rooms plus a short extension to the west. The target room will contain all of the beam handling system as well as the experimental areas. A wide door on the lower floor allows access for large equipment. A corner of the room houses a shielded neutron irradiation source for use in student experiments.

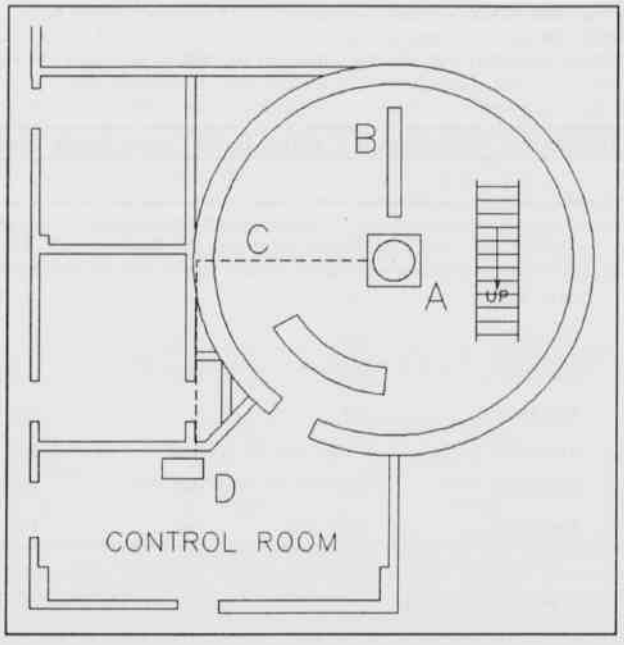

Figure 1. U.C.A. Accelerator Area - upper floor

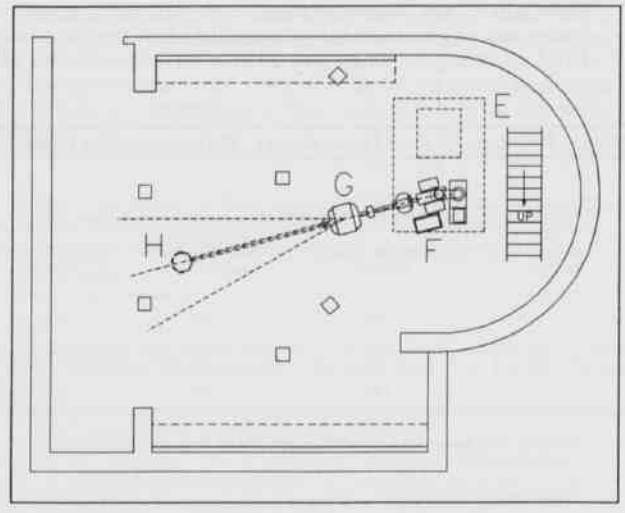

Figure 2. U.C.A. Accelerator Area - lower floor

The dashed outline denoted (E) in Fig. 2 represents an extension of the target room below floor level. This region is designed for future use as a neutron irradiation area; the floor of the target room in this area is heavily shielded. The remainder of the neutron area is approximately 6.1 m below outside ground level and consequently well shielded. This region will allow experiments that produce relatively high radiation exposures to be conducted. This area is also part of the interlocked safety system.

The beam line components and other equipment shown in Fig. 2 will be mentioned at the appropriate points in the discussion of the accelerator installation which follows.

The machine itself was originally a long column 2.5 MV electron accelerator; the reduction of the column in length provided room for the installation of a positive terminal; this was a common modification of the series. The machine arrived at our school with all of the major components, i.e., console, base assembly, column, accelerating tube, and drive and cooling systems, essentially intact and in good condition.

Considering the usual financial and time constraints, the work on installation has progressed well. A substantial amount of time went into basic mechanical installation of the base and column assemblies. The machine was in place and assembled within a year and console wiring was largely in place; belt drive and charging systems were installed and tested. Console functions relating to basic machine operation were wired and checked.

Our use of the accelerator will be entirely with positive ion beams. As the accelerator was originally designed for electron beams, we had to provide a positive potential terminal and an ion source. The construction of these items took place after the main components were in place. The terminal supports and powers various power supplies necessary to operate the ion source, which is a conventional RF bottle source that produces a beam of very low energy ions by electron stripping in a high frequency electric field and concentration by an axial magnetic field. The primary use of this machine will involve the production of proton beams. The ion source gas handling system will allow the changeover of source gas without disruption of tank pressure or source vacuum.

As the terminal and ion source are at high potential relative to the baseplate, ion source parameters such as pressure, extraction voltage, and beam focus voltage are controlled by insulating rods extending up through the column. Stepper motors drive these rods. The controllers for the motors were designed and built in the lab; the console controls for these were installed and the ion source was tested for basic operation.

Subsequent and recent work has been devoted primarily to the beam handling system. The beam system exits the accelerator downward into a 4 inch beam line. This line also contains the first of what will be several vacuum pump stations. The tube and beam line vacuum currently is being maintained by a conventional oil diffusion pump; the system has not been rigorously sealed nor leak-chased at this point as there are beam line modifications to be made in the near future.

The downgoing beam line terminates at the entrance port of a 90° bending magnet (F in Fig. 2). This magnet holds a pair of large water cooled coils on either side of a beam line segment, producing a horizontal magnetic field. This has the effect of turning the beam into the horizontal direction where it exits the magnet about 0.9 m above the floor level. This is the extent of the existing beam line. The construction of concrete support pillars and positioning equipment for the substantial burden of the magnet has been completed during the past few months.

Immediate plans include the installation of the bending magnet power supply and its associated plumbing and wiring. The remaining steps necessary to test the accelerator for beam production will be completed during the remainder of the spring and summer of this year. The short range aim is to have basic beam production and transport from the accelerator at nearly the design energy of 2.5 MeV by the end of summer 1990.

Figure 2 also shows the major items remaining to be designed, built, and installed. Some of these items are commercially produced, but the majority of the beam line and vacuum system will be constructed in the lab.

The beam will continue from the exit port of the first magnet through a beam line section which will also contain another vacuum pump station. From this section it will enter another magnet (G), the switching magnet, which will steer the beam into one of 3 beam lines leading to 3 experimental stations. This will allow several experimental setups to use the accelerator without conflict. The layout of these lines was dictated by both the fixed exit angles of the switch magnet and the support posts for the shield wall above. Each of these beam lines will terminate in a scattering chamber (H) in which beam particles interact with the target and in which detectors are mounted to detect the products of the resulting reactions. A third vacuum pump station is planned for the scattering chamber area.

General Notes

Extensive work remains to be done in a number of areas in the lab. Foremost among these after the basic accelerator functions are established are design and construction of equipment to measure and regulate the beam energy with precision. Other necessary projects include improvements to the vacuum system and its gauging capabilities, beam focussing and diagnostic equipment and electronics, and target chamber design.

In summary, a positive ion accelerator is being installed at the University of Central Arkansas. The major hurdles involved in the machine installation and checkout have been passed, and basic beam production is expected in the relatively near future. This laboratory will enable the physics department to offer its students valuable experience with experimental techniques and procedures in a research environment not commonly found in our type of institution.

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A SYNOPSIS OF THE BELOSTOMATIDAE OF ARKANSAS

There have been no studies treating specifically of the Belostomatidae of Arkansas. Pertinent information is either in taxonomic studies which include Arkansas material (Menke, 1958; 1963) or lists of aquatic macroinvertebrates from particular sites within the state (Harp and Harp, 1980; Farris and Harp, 1982; Huggins and Harp, 1983). The purposes of this paper are to present the first statewide species list, to delineate geographic distributions, and to define preferred habitats for belostomatid species, insofar as present knowledge will allow. Arkansas species may be identified by using Gonsoulin's (1973) key to Louisiana species.

Most information presented has been compiled from specimens in the ASU Aquatic Macroinvertebrate Museum; however holdings of the ASU Entomological Museum, and UA-Fayetteville Museum, and UA-Little Rock Entomological Museum were examined, and literature records are included. Finally, 2 collecting trips were made to south and central Arkansas counties to diminish distributional gaps in the data.

Belostoma lutarium (Stal) was first reported from Arkansas by Menke (1958). It is our most common species of *Belostoma,* being represented from 278 collections in 51 counties (Fig. 1). Froeschner (1962) listed only one Missouri specimen but suggested it should occur widely in the state. Gonsoulin (1973) reported this as the most common species of the genus in Louisiana, being found in all aquatic habitats in the state. Wilson (1958) stated that this species was very common in Mississippi, being collected in shallow brackish pools and stock ponds filled with submerged and emergent vegetation. This species occurs in all aquatic habitats in Arkansas, in all physiographic provinces; however, it was most often collected in lowland ponds, streams, and lakes, and in ditches and bayous within the Mississippi Embayment, the Gulf Coastal Plain and Crowley's Ridge. The Louisiana collections include specimens captured during all months except February, May, September and December; the Missouri specimen was collected in July; the Mississippi bugs were collected March-November (Wilson, 1958; Froeschner, 1962; Gonsoulin, 1973). In Arkansas this species has been taken in all months of the year.

Belostoma flumineum Say has not been reported previously from the state. It has been taken in 48 collections in 15 counties in Arkansas (Fig. 2). This is the most common species of the genus in the United States (Gonsoulin, 1973). It has been found year round in Missouri (Froeschner, 1962) and is expected to occur throughout the state. It ranks far behind *B. lutarium* in distribution in Louisiana with collections in March and July from sluggish streams or marsh areas with abundant aquatic vegetation (Gonsoulin, 1973). Wilson (1958) reported this species from stagnant waters in Mississippi. The Arkansas specimens were collected every month except December and in 3 physiographic provinces, the Ozarks, Mississippi Embayment and Crowley's Ridge. Approximately one-half were collected from Ozark streams and one-third from lowland ponds. They also occurred in Ozark ponds and lakes and lowland streams.

Belostoma testaceum (Leidy), not previously reported from Arkansas, was taken in 13 collections in 10 counties (Fig. 3). This species has a fairly wide distribution in Louisiana and was found in June, August, October and November (Gonsoulin, 1973). One specimen was taken in Mississippi from a shallow, shaded pool in a dense swamp (Wilson, 1958). Though not reported from Missouri, it is expected to occur there (Froeschner, 1962). Habitat was not recorded in previous studies (Foreschner, 1962; Gonsoulin, 1973). In Arkansas this species (collected March, April, June, September, October, November, December) was most often found in lowland ponds and rivers, roadside ditches and swamps in the Mississippi Embayment and Crowley's Ridge.

Huggins and Harp (1983) first reported *Belostoma fusciventre* (Dufour) from Arkansas. It is the least common belostomatid in the state, occurring in only 2 collections from 2 counties (Fig. 4). Gonsoulin (1973) recorded a large range extension for this species, which had previously been documented from southern Texas and southeastern Arizona; however, it is not found on the Missouri list (Froeschner, 1962). Habitats from which this species was taken are a lowland creek in the Ouachitas (Arkansas River Valley) and a lowland pond in the Gulf Coastal Plain, both of which appeared to have good quality water. In Louisiana this species was taken in July, August and October; in Arkansas, it was collected in July and November.

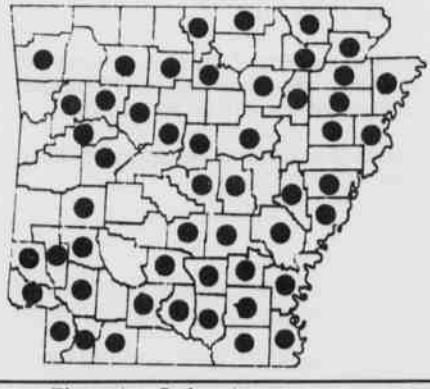

Figure 1. *B. lutarium*

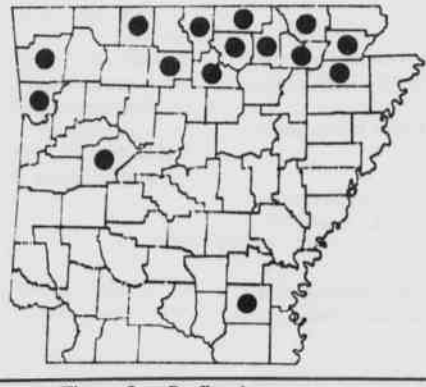

Figure 2. *B. flumineum*

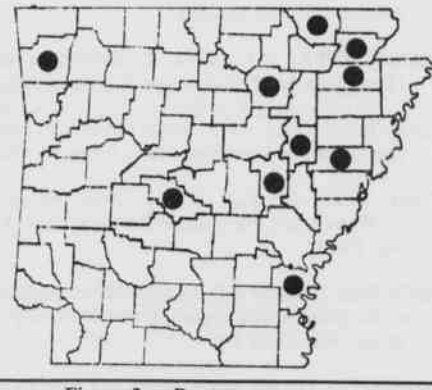

Figure 3. *B. testaceum*

Lethocerus uhleri (Montandon) is the most common species of this genus in Arkansas with 86 collections in 24 counties (Fig. 5). This species was first reported in Arkansas by Menke (1963). These bugs are attracted to lights at night, where they are most often collected (Gonsoulin, 1973). Eight of 14 aquatic collections occurred in lowland ponds, while 7 were found in lowland streams, rivers, lakes and ditches in the Gulf Coastal Plain, Mississippi Embayment and Crowley's Ridge. This species is judged to be common in both Louisiana and Missouri, being collected during June, July and September in the latter (Gonsoulin, 1973; Froeschner, 1962). *L. uhleri* is common in Mississippi where it is frequently collected at lights (Wilson, 1958). This species was taken in Arkansas in every month except June and December.

Lethocerus griseus (Say) also was previously reported from Arkansas by Menke (1963). This species is the second most common of the genus, being taken in 19 collections in 12 counties (Fig. 6). Those few specimens for which habitat data were available were captured at lights. These bugs are reported from sluggish and still waters throughout Missouri (Froeschner, 1962). *L. griseus* is also distributed throughout Louisiana and has been taken there in slow moving or stationary bodies of water with abundant aquatic vegetation (Gonsoulin, 1973). In Mississippi it is active during the warm months and is collected in ponds, streams, borrow pits and lights (Wilson, 1958). Specimens were captured during April, May, June, July, August and October in Arkansas.

Lethocerus americanus (Leidy) has not been previously recorded from the state. One Arkansas specimen is recorded as captured at a street light (Fig. 6). Gonsoulin (1973) reported this species from Louisiana but questions its occurrence since a single specimen taken in 1886 was unavailable to him. Although no specimens have been recorded from Missouri or Mississippi, Froeschner (1962) and Wilson (1958) listed this species; both suggested it should occur in their states because of its known range. The collection in Arkansas was in August.

It is hypothesized that all 7 belostomatid species can be collected during any month of the year in Arkansas. Most should be found in all physiographic regions. *Belostoma flumineum* and *B. fusciventre* may be restricted in their distribution, however, appearing to prefer good quality waters.

Figure 4. *B. fusciventre*

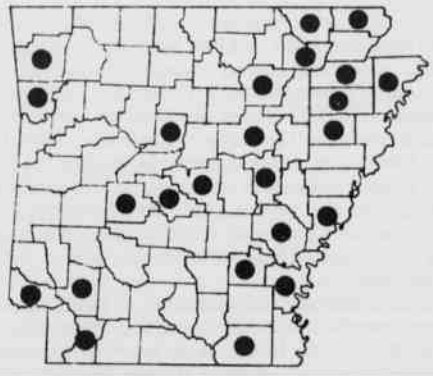

Figure 5. *L. uhleri*

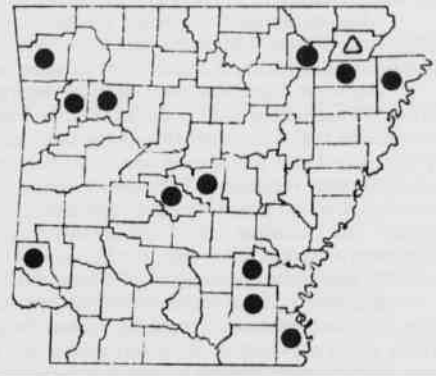

Figure 6. *L. griseus* • *L. americanus* Δ

ACKNOWLEDGMENT

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General Notes

MANAGEMENT OF THE OZARK BIG-EARED BAT, *PLECOTUS TOWNSENDII INGENS,* IN ARKANSAS

The Ozark big-eared bat, *Plecotus townsendii ingens,* is one of 5 recognized subspecies of Townsend's big-eared bat, *P. townsendii* (Handley, 1959). Of the 5 races, only the Ozark big-eared bat and the Virginia big-eared bat, *P. t. virginianus* (occurring in Kentucky, Virginia, West Virginia, and North Carolina), are currently listed as endangered by the U.S. Fish and Wildlife Service.

Ozark big-eared bats are cave residents year-round, although different caves are usually occupied in winter and summer. They hibernate in caves (sometimes mines) where the temperature is 12° C or less, but generally above freezing. Cave hibernation sites are often near entrances in well-ventilated areas. If temperatures near entrances become too extreme, they move to more thermally stable parts of the cave. Ozark big-eared bats hibernate in tight clusters of a few to a hundred or more individuals. During hibernation, the long ears may be erect or coiled. Solitary bats sometimes hang by only 1 foot.

Ozark big-eared bat maternity colonies are usually located in relatively warm parts of caves. During the maternity period, males are apparently solitary. Where most males spend the summer is unknown. Mating begins in autumn and continues into winter. Young females apparently mate during their first autumn. Sperm are stored during winter, and fertilization occurs shortly after arousal from hibernation. A single pup is born during June.

Prior to 1975, Ozark big-eared bats had been reported in small numbers from only a few caves in northwestern Arkansas, southwestern Missouri, and eastern Oklahoma (U.S. Fish and Wildlife Service, 1973; Handley, 1959). The U.S. Fish and Wildlife Service (1973) estimated the total number surviving to be less than 100 and reported that no more than 4 individuals had ever been found at one time. That information was incorrect; Sealander (1951) reported collecting 11 Ozark big-eared bats from a Washington County, Arkansas, cave in 1951.

It was not until 24 years later that a number greater than 11 was reported. Harvey (1975) and Harvey *et al.,* (1978) reported finding 60 hibernating *P. t. ingens* in a western Arkansas (Washington Co.) cave in February 1975.

During the summer of 1978, the first known Ozark big-eared bat maternity colony was discovered, in a Marion Co., Arkansas, cave. The colony consisted of ca. 120 females and young (Harvey *et al.,* 1981). During the following winter (March 1979), a hibernating colony of ca. 255 *P. t. ingens* was discovered in another Marion Co. cave, only ca. 6 km from the maternity cave (Harvey *et al.,* 1981).

The Washington Co. hibernating population has fluctuated since 1975, with no more than 60 reported during any 1 winter. During February 1990, only 8 individuals were observed in the hibernaculum, however, ca. 60 were present during the winter of 1988. The Marion Co. hibernating population has varied from a high of 420 in 1980 to a low of 140, during February 1990.

The Marion Co. maternity population has varied from a high of 170 in 1979 to a low of 46 during the summer of 1986. During the most recent estimate (July 1989), ca. 83 adults and young were observed exiting the maternity cave.

These 3 sites are the only Arkansas caves where colonies of Ozark big-eared bats have regularly been found, although scattered individuals or groups of 2-40 have been reported from other caves. We currently estimate the total Arkansas population at ca. 200 individuals.

During recent years, both hibernating and maternity colonies of Ozark big-eared bats have been discovered in several eastern Oklahoma caves. Approximately 1400 are currently estimated to occupy Oklahoma caves (Brenda S. Clark, pers. comm.). None are presently known to exist in Missouri caves. Thus, the total known *P. t. ingens* population numbers ca. 1600 individuals.

The Marion Co. hibernation cave (housing ca. 140 *P. t. ingens*) and ca. 83 ha of surrounding land were purchased by the Nature Conservancy and are now under the jurisdiction of the Arkansas Natural Heritage Commission. The cave has not been gated or fenced, and there are currently no plans to do so. A warning/interpretive sign has been placed at the entrance and the access road to the cave has been gated. The bats hibernate in a section of the cave where humans are not likely to find them, and the cave apparently receives relatively little human visitation. It is felt that a gate is unnecessary (and would be very expensive to construct).

The Washington Co. hibernation cave is located in Devil's Den State Park. A management plan for the cave is being formulated, but has not been completed. Park naturalists are very much concerned about the welfare of the bats and take precautions to prevent park visitors from disturbing the colony when it is present. A warning/interpretive sign has been placed at the cave entrance, and a security alarm system will be installed in the near future.

The Marion Co. maternity cave has been offered protection through a cooperative agreement with the landowner and by an angle-iron gate constructed in 1987 by the Arkansas Game and Fish Commission, utilizing endangered species funds from the U.S. Fish and Wildlife Service.

Ozark big-eared bat populations at these 3 important caves are monitored annually or biennially. Spelogers, battery operated electronic devices that record the date and time of human intrusion into the caves (triggered by light), have been used to determine the extent of disturbance. Attempts are also being made to locate additional *P. t. ingens* colonies.

A program to educate the public about the beneficial nature of all Arkansas bats and their importance in the ecosystem is also being conducted. Numerous bat programs have been presented to the public, and several thousand copies of a 48-page booklet entitled "Arkansas Bats: A Valuable Resource" (Harvey, 1986) have been distributed. Hopefully, management measures taken or planned will result in stable or increasing populations of the endangered Ozark big-eared bat, as well as all Arkansas bats.

ACKNOWLEDGMENT

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PELLET ANALYSIS OF WINTER-ROOSTING LONG-EARED OWLS *(ASIO OTUS)* IN ARKANSAS

The Long-eared Owl *(Asio otus)* is rather rare in Arkansas, with only about two dozen individuals recorded in the state in the past 30 years (James and Neal, Arkansas birds: their distribution and abundance, 1985, p. 210); (Muth, Am. Birds 39:177, 1985; Am. Birds 40:291, 1986; Am. Birds 42:277, 1988). Herein I report on the contents of owl pellets from 2 Long-eared Owls found in northeast Arkansas. On 6 December 1988 I discovered a dead Long-eared Owl on railroad tracks at the NE corner of the Jonesboro municipal airport, Craighead County. Subsequently 2 live individuals roosting close to the trunk of a small oak tree at a height of 3 meters, in a wet scrubby area along the railroad tracks were observed. They could be found each day in the identical spot until 19 January 1989, after which they were not seen. Sixty-two pellets were picked up under their perch and analyzed for the animal remains they contained as an index of the owls' feeding. Pellet contents and percent occurrence in total pellets were as follows: house mouse *(Mus musculus)* 41.3; unidentified bird species (Passerines) 14.9; unidentified rodent remains 11.5; marsh rice rat *(Oryzomys palustris)* 6.9; *Microtus* spp. 5.7; southern short-tailed shrew *(Blarina carolinensis)* 4.6; least shrew *(Cryptotis parva)* 3.5; prairie vole *(Microtus ochrogaster)* 3.5; Norway rat *(Rattus norvegicus)* 3.5; hispid cotton rat *(Sigmodon hispidus)* 2.3; and southern bog lemming *(Synaptomys cooperi)* 2.3. The species taken, and the percentages of each, conformed closely to the types and numbers of small vertebrates likely to be encountered at that time and place (Van Rick McDaniel, pers. comm.), and indicated that the Long-earned Owl, during the winter in Arkansas, is an opportunistic nocturnal predator. This agrees with the results of other studies of feeding habits of this species (e.g. in Bent, Life histories of North American birds of prey, part two. U.S. Natl. Mus., Bull. No. 170, 1938).

The author thanks Van Rick McDaniel for help in the identification of mammal species.

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ENHANCING AN ENGINEERING LEARNING ENVIRONMENT

As part of a Title III grant from the Department of Education, Christian Brothers University initiated a focused effort to incorporate critical thinking and enhanced communication abilities into the freshman engineering sequence. One of the first courses targeted for this incorporation was the introductory FORTRAN course which is required of all engineering and engineering physics majors. This course is an elective for computer science and science majors.

The modification to the course consisted of 4 major components. The first component was the introduction and use of a problem solving paradigm. Research by Charles Wales of West Virginia University (Wales, ASEE Volume 78, Number 7, p. 687, 1988) and Donald Woods of McMaster University (Woods, Strategies, p. 4-1, 1985) determined that student performance improved with the use of a problem solving paradigm. The paradigm that was used consists of seven steps:

1. I want to and I can — Students were encouraged to motivate themselves and prepare before starting a problem.
2. Define the situation — Students were prompted to try to understand the words of the problem, to analyze the statements concerning the problem, to identify constraints, to identify criteria, and, where applicable, draw diagrams and sketches.
3. State the objective — Students were required to write down exactly what they wanted to accomplish.
4. Explore the options — Students were expected to play around with ideas, make connections, collect information, and postulate possible solutions.
5. Plan — Students selected and developed a plan for solving the problem.
6. Do It — Students worked the problem in this step.
7. Look back — Students were asked to evaluate their performance. They were asked to check and double check, identify experience factors, extend to similar problems encountered, and determine what they learned about problem solving.

This same problem solving paradigm has been used in chemistry and physics courses. The student response to the problem solving paradigm was generally positive. Hesitation about the paradigm centered around the concern that following the 7 steps made the problem solving process longer. A typical student comment about the problem solving paradigm was, "Using the paradigm makes me stop and really think about what I am doing. It requires me to organize my thoughts, but this sometimes takes too long." A typical student misconception concerning the paradigm was that the problem solving paradigm is serial. Some students believed that once they completed the "define the situation step" that they should never return to that step! The majority of students expressed the opinion that the problem solving paradigm had been helpful in solving problems.

The second modification introduced was the use of guided design and discovery techniques. Prior to the modification, students were given lectures explaining programming theory before writing or seeing programs which exhibited those techniques. The student interest in the theory was low and little concerning the theory was retained. Kobl (Kolb, The Modern American College, Chapter 10, 1981) has suggested that students learn better when they start with a concrete experience. Now students are given a structured and well documented program which exhibits the desired programming theory before the theory is discussed. For example, on the first day of class, students are taken to the computer lab and asked to create a simple program. The program prompted the student to enter 3 numbers and then the program displayed the average of the 3 numbers

on the screen. The students were first asked to compile, link, and run the program with a few sample cases. Next the students are asked to change the declaration of variables in the program from type real to type integer. They are asked to edit, compile, link, and run the program again and observe the differences. Finally, they were asked to read the program and hypothesize what each statement accomplishes. When the program was discussed in class, some students had already figured out what most of the program did. Those students who were not sure about the program had many questions and were motivated to learn about programming. The shift to self-discovery has increased students' participation and given them a sense of "ownership" concerning the course. There were a few students who were uncomfortable with self-discovery and wanted to know the "answers" before working on any program. These students performed well and their sense of discomfort seemed to be with the shift of responsibility. Usually, by the fourth week of class, students adjusted to the shift and expressions of anxiety decreased.

The third modification introduced in the course was the use of journal keeping as a learning and communication tool. (Knoblauch and Brannon, College English 45:5, pp. 465-474, 1983) Prior to the introduction of writing as learning, engineering students had been required to keep design journals. The focus of these journals was primarily on documentation. The focus has now been expanded to include not only the students' observations but also their feelings, guesses, and reflections concerning their own learning process. Students were given assignments to write in their journals in the classroom and outside of the classroom. As an example, on the first day of class, students were given a syllabus which outlined course goals. They were then asked to write down their initial reaction to the syllabus and select the course goal which was most important to them. In the process of thinking about the course goals, some students changed their perception of FORTRAN. The course was transformed from a dreadful required course to a possibly useful course.

The journals were also useful to the instructors. By reading students' thoughts and feelings concerning the material, it was possible to find and correct misconceptions concerning FORTRAN. In addition, it was readily apparent when a student understood a concept and it was possible to monitor a student's progress in the class. The journal also added a personal communication link between the student and instructor. When students realized that the journals were confidential, they began to vent concerns and frustrations that they did not feel free to express in class. As the last journal assignment in the course, students were asked to re-read their journals and reflect on the usefulness of the journals. The majority of students found the journal keeping helpful. Those who did not find the journal helpful made comments such as, "I do not believe that the journal actually helped me in my learning. It may have pointed out any problems I have to the instructor, so that I could receive help."

There were some students who were exhuberent about the use of the journal. It was gratifying to read entries such as the one below:

> Can I see any evidence of growth???? When I came to this class, I knew nothing at all about FORTRAN. This seems like such a short time ago. I can't believe all of the things I know now. My growth in this class can be compared to the size I was at one day old as compared to my size at 18 and one day....I would recommend using journals in FORTRAN next semester. I will admit that I thought it was dumb at first, but after looking back on it, I think it was a very good idea. The fact that I can now look back and see just how far I have come in so little time justifies using the journals tenfold.

The fourth modification introduced was the concept of assessment as learning. (Mentkowski and Loaher, Assessing Educational Outcomes, p. 47, 1985) Specific criteria were developed for each assignment. These criteria were not exact instructions but rather the rules for evaluating a student's performance on each assignment. Each student was asked to evaluate his/her performance on each assignment. In addition, the instructor gave timely feedback to each student concerning the student's performance. Initially, students tended to rank their performance on assignments much higher than the instructor. Through the feedback process, many students began to develop the ability to self-assess their work. As an example, to introduce control structures students were asked to input and test a simple program. The requirements and criteria for the assignment were as follows:

I. REQUIREMENTS

1. Enter the program. Compile, link, and run the program with various inputs. Try to select inputs which represent normal operating conditions and others which test the limits of the program. Create a table of these results for inclusion in your submission. Justify all values which you select to test.
2. Explain in your own words what the program is doing. If you had been the programmer, how would you have changed the way that this program is written?
3. Propose a structure to handle the case in which there were 3 possible alternatives for the calculation....
4. In the program that you entered into the machine, what error do you receive if the END IF statement is not entered?
5. Submit at least one page detailing what you have learned fromthis assignment.
6. Submit a self evaluation of your performance on this assignment. Assign yourself an evaluation of Excellent, Good, Acceptable, or or Unacceptable. Support yourself in terms of the criteria shown below.

II. CRITERIA

1. Completeness of the submission as detailed in the requirements. Failure to submit any of the above components of the assignment will result in an evaluation of Unacceptable.
2. Thoughtfulness and completeness of the testing as outlined in requirement 1.
3. Depth of explanation of what the program is doing. This is to be an ENGLISH explanation of what the structures in the program are doing. Unknown structures should be solved based on how they behave in program operation.
4. Accuracy of the alternate control structure in requirement 3.
5. Accuracy of the results in requirement 4.
6. Length and depth of "what you have learned" and "self evaluation" sections. This should be an HONEST evaluation and should be given careful consideration. It is not an add on to be completed at the last minute.

To help students understand the expectations for excellent work, examples of excellent work were shared with the class. By the end of the semester, students reacted positively to criteria based learning.

In conclusion, the modifications made to the introductory FORTRAN course have been received favorably. Student participation and performance have increased.

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TIME COURSE OF PHOTOREACTIVATION OF UV INDUCED DAMAGE IN G1 PHASE XENOPUS CELLS THAT LEADS TO CHROMOSOME BREAKS OBSERVABLE BY PREMATURE CHROMOSOME CONDENSATION

In a study of the time course of photoreactivation (PR) of UV-induced primary lesions in the DNA of G1 phase *Xenopus* cells, Griggs and Payne (1981) observed that most of the lesions that led to chromosomal aberrations could be efficiently photoreactivated while the cells progressed through G1 phase. However, these lesions appeared to somehow be converted to a nonphotoreactivable state as the cells entered S phase. Since, in chromosomal aberration production, the chromosome strands are apparently first broken and then the resulting fragments are improperly rejoined or left unattached, and since PR of aberrations requires that administration of photoreactivating light precede the chromosome breakage, these observations by Griggs and Payne (1981) were interpreted as follows: Most of the photoreactivable UV-induced primary lesions in the DNA of G1 phase *Xenopus* cells that lead to chromosome breaks lie essentially dormant as the cells progress through G1 phase. These lesions are expressed as chromosome breaks in the cells as they enter S phase, perhaps by some mechanism associated with unwinding of the double helix for DNA synthesis. Chromosomal aberrations observable in the cells when they reach the first succeeding mitosis result from improper joining of broken chromosomal fragments. We briefly describe here the first of a set of studies designed to examine the validity of this interpretation.

Among the implications of the interpretation are the following: (1) If UV irradiated G1 phase *Xenopus* cells could be following: (1) If UV irradiated G1 phase *Xenopus* cells could be examined periodically for chromosome breaks as they progressed through interphase, no significant frequency of chromosome breaks would be observed until the cell entered S phase. (2) The frequency of these UV-induced breaks could be decreased by PR only if the PR light was administered to the cells while in G1 phase. We recently developed a premature chromosome condensation (PCC) technique for observing interphase *Xenopus* chromosomes making it possible to test these implications experimentally.

The cell line used was the A86 *Xenopus* line described by Kulp and Griggs (1989). This line has an exceptionally stable karyotype of 36 chromosomes (Fig. 1). Techniques used for obtaining synchronous cultures of G1 phase cells, incubations, UV and PR irradiations, tritiated thymidine flash labelling, preparation of autoradiographs, and mitotic index determinations were the same as described in detail by Griggs and Bender (1972, 1973), Griggs and Orr (1979), and Griggs and Payne (1981). The PCC technique developed was similar to those described for scoring breaks in interphase mammalian chromosomes by Waldren and Johnson (1974), and Pantelias and Maillie (1985). A typical G1 phase PCC cell (cell with prematurely condensed chromosomes) is shown in Fig. 2.

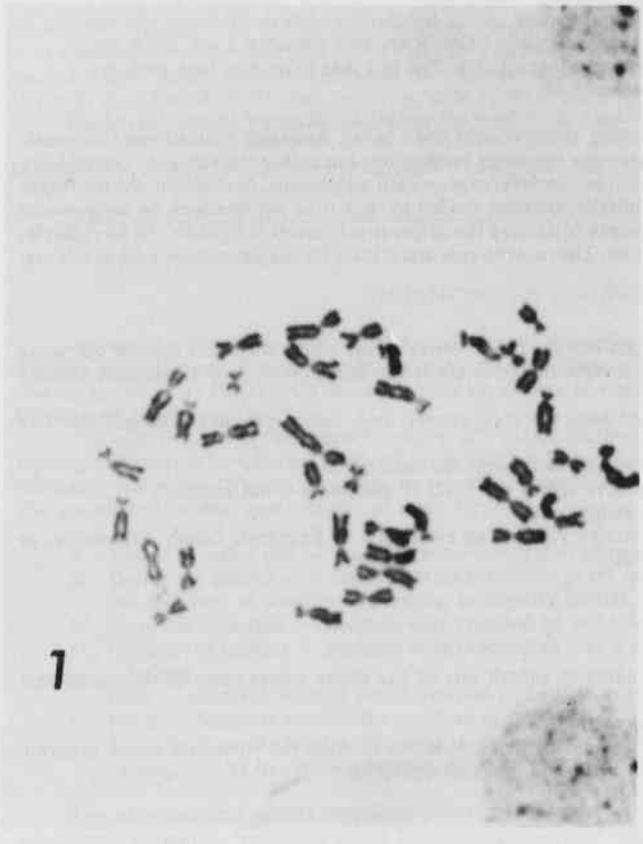

Figure 1. A typical metaphase spread for normal A86 *Xenopus* cells.

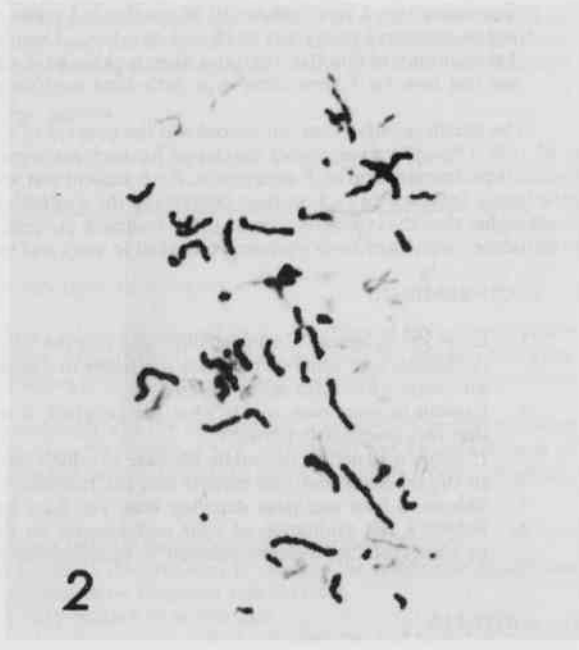

Figure 2. A PCC A86 *Xenopus* G1 phase chromosome spread. The differential chromosome staining technique, developed by Perry and Wolff (1974), was used to stain the G1 phase monopartite (single stranded) chromosomes more deeply than the bipartite metaphase chromosomes.

Results of the experiments are shown in Table 1. The starting point for each experiment was UV-irradiation of synchronous cultures of G1 phase cells, 4 hours after mitotic selection. As these irradiated cells progressed through the remainder of G1 phaSe and part of S phase, they were photoreactivated, flash labelled with ³HTdR and subjected to PCC as indicated in Table 1. Autoradiographs of the cells were then prepared on microscope slides and PCC cells were selected at random from these slides and scored for chromosome breaks.

Three particularly relevant observations can be made by focusing on the data of certain subsets of the experiments: (1) Comparison of the data of experiments 1-4 with that of experiments 5-10 reveals that the radiation fluences administered in the latter experiments did not significantly

General Notes

Table 1. Time course of appearance of chromosomal breaks in *Xenopus* cells that were exposed to UV in G1 phase, and time course of PR of these breaks.

Experiment number	UV fluence (J/m^2)*	PR fluence (J/m^2)	PR time (hrs after UV)	3HTdR labelling time (hrs after UV)	Number of PCC cells scored**	Number of breaks scored per cell	Percent of PCC cells labelled
1	0	0		2.50	150	0.012	0
2	0	0		3.00	150	0.011	4
3	0	0		3.50	150	0.010	5
4	0	0		4.00	150	0.012	96
5	18.0	0		2.50	150	0.010	6
6	18.0	2×10^4	0.5	2.50	150	0.010	7
7	18.0	0		3.00	150	0.015	5
8	18.0	2×10^4	0.5	3.00	150	0.012	6
9	18.0	0		4.00	150	0.115	95
10	18.0	2×10^4	0.5	4.00	150	0.030	96
11	18.0	0		5.00	150	0.125	94
12	18.0	2×10^4	0.5	5.00	150	0.025	95
13	18.0	0		7.00	150	0.115	96
14	18.0	2×10^4	7.5	7.00	150	0.120	95
15	18.0	0		10.00	150	0.120	94
16	18.0	2×10^4	10.5	10.00	150	0.110	94

* UV was administered 4 hours after mitotic selection. ** PCC was induced shortly after labelling and PR.

influence the progress of the cells through G1 phase into S phase; furthermore, the cells entered S phase about 3-3.5 hours after the UV exposure. (2) Consideration of the data of the control experiments (1-4) in conjunction with the data of the experiments in which the cells received UV but no PR light (5, 7, 9, 11, 13, and 15), reveals that the number of chromosome breaks observed in the latter experiments exceeded that observed in the control experiments only after about 4 hours past the UV exposure (experiment 9); which (by observation 1) was after the cells had entered S phase. Observation 1 combined with observation 2 appears to adequately confirm implication 1. (3) Comparison of the data of experiments 5, 7, 9, 11, 13, and 15 with the data of experiments 6, 8, 10, 12, 14, and 16, respectively, indicates that UV-induced chromosome breaks were photoreactivated only in experiments 10 and 12 in which PR light was administered 0.5 hours after the UV exposure; which by observation 1 was during the G1 phase. Thus, observation 1 combined with observation 3 appears to confirm implication 2.

In conclusion, the results of the experimentation described here tend to support the interpretation by Griggs and Payne (1981) by confirming two of its implications. These results also suggest that additional appropriate experimentation of this nature may further strengthen the interpretation.

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Correction — In the article "Reproductive characteristics of south Florida *Sternotherus odoratus* and *Kinosternon baurii* (Testudines: Kinosternidae)" by Walter E. Meshaka that appeared in Volume 42 (1988) of the Proceedings of the Arkansas Academy of Science, pages 111-112, the following correction should be noted. In the third paragraph, the first sentence should read "Average carapace lengths for eighteen sexually mature females (77 + 5.69; range = 62-86) and ten sexually mature males (68 + 8.79; range = 52-80) support Tinkle's (1961) findings of sexual dimorpism in southern populations."

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FLEMING, T. H. 1969. Population ecology of three species of neotropical rodents. Unpublished Ph.D. dissertation. Univ. Michigcan, Ann Arbor, 231 pp.

JONES, I. C. 1957. The adrenal cortex. Cambridge Univ. Press, London, 316 pp.

WRIGHT, P. L. 1966. Observations on the reproductive cycle of the American badger *(Taxidea taxus)*. Pp. 27-45, *in* Comparative biology of reproduction in mammals (I. W. Rowlands, ed.) Academic Press, London, xxi + 559 pp.

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